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FINAL PROGRESS REPORT

For the Period 1 April - 30 September 1980

Dispersal of stage II western spruce budworm larvae
and flight behavior and dispersal of adults as related
to stand conditions and silvicultural practices.

Prepared by
David G. Fellin

January 1981

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PREFACE

This is the final progress report of one of three studies currently underway at the Forestry Sciences Laboratory in Missoula, Montana, as part of the Intermountain Forest and Range Experiment Station's involvement in the CANUSA Program-West. Though each study is discrete, all three studies are closely related. The principal investigators for, and the activities addressed by, the other two studies are: 1) Raymond C. Shearer and Charles F. J. Tiernan, activity 3.1.1 and 1.2.5; and 2) Dr. Clinton E. Carlson, activity 3.1.1 and 2.3.1.

The three studies are all being conducted through an entomological-silvicultural research team headquartered at the Forestry Sciences Laboratory at Missoula, Montana. All of these studies are also being closely coordinated with related Program studies, especially those being conducted by investigators at the INT Forestry Sciences Laboratory at Moscow, Idaho.

This final report:

1. Includes some material already presented in progress reports submitted to the Program in November 1978, October 1979, and March 1980.
2. Presents statistical analysis and interpretation of 1978 and 1979 data not included in the above reports.
3. Incorporates material submitted to the Program in proposals or proposal revisions in February 1978, May 1978, January 1979, August 1979, October 1979, and February 1980.

This is to be considered the final report of research funded by the Program between April 1, 1978 and September 30, 1980.

INTRODUCTION

The western spruce budworm, *Choristoneura occidentalis* Freeman, has been a persistent and influential agent in the management of Northern Rocky Mountain forests for more than 25 years. Following its discovery in northern Idaho in 1922, scattered infestations developed in Idaho and Montana through the late 1920's and into the thirties. In the late 1940's more persistent outbreaks began developing in western Montana and by the mid-1950's there were nearly 5 million acres of budworm-infested forests in west-central Montana. Most of these forests, particularly east of the Continental Divide, are characterized by extensive stands (mostly overstocked) of pure Douglas-fir growing on relatively poor sites.

Direct control programs against the western spruce budworm have been generally unsatisfactory. Between 1952 and 1963, 2,880,000 acres of infested forests were treated with DDT at the rate of 1 pound of insecticide per gallon of fuel oil per acre. Because of reinvasion of treated areas from adjacent untreated areas or a population resurgence from survivors within the sprayed areas, many forests were sprayed twice and even three times. The reduction in budworm populations by the insecticide did allow trees and stands some respite from the damage and no doubt prevented considerable tree mortality. However, in spite of the treatment (or because of it) the budworm outbreak in western Montana persisted.

In the mid- to late-1960's, outbreaks generally east of the Continental Divide began subsiding and new infestations were developing northward and westward from Missoula. Through the early 1970's the acreage and intensity of infestations continued to increase on several forests in western Montana and especially in northern Idaho. Interestingly, in the early 1970's budworm infestations resurged on some forests east of the Divide.

With its development in northern Idaho and adjacent western Montana forests, the budworm invaded more and more mixed stands--there are at least nine coniferous species in three major forest series--Douglas-fir, grand fir, subalpine fir--which serve as food or a substrate for the budworm in one or more stages of its development. In some of these hosts WSBW larvae do not confine their feeding to the current foliage. Recent observations have shown that budworm larvae feed in and on the cones of western larch, Englemann spruce, subalpine fir, and Douglas-fir. Moreover in western larch, heretofore considered a non-host species, budworm larvae sever terminal and lateral shoots which jeopardizes straight form and rapid juvenile height growth of young trees by producing crooked and misshapen trees resulting in a net loss in height growth of from 24 to 30 percent. Feeding by WSBW larvae has resulted in drastically reduced growth rates in some of our more productive forests, mortality, esthetic deterioration, and a host of other less well defined losses. Natural regeneration has been nearly impossible to establish where WSBW has persisted.

At this time there are still more than 4 million acres of predominantly mixed coniferous forests on ten Region One National Forests, and in Yellowstone National Park, and the Flathead Indian Reservation, infested (aerially visible) by the western spruce budworm. There are no indications that budworm damage will diminish or that the outbreak will not continue unabated.

JUSTIFICATION

In the Northern Rockies, forest managers for some time have recognized the forest regeneration failures in western spruce budworm-infested forests. Some of this is attributable to the decimation of cones and seeds of some species. Also involved is the impact of feeding larvae on young trees, an impact that undoubtedly varies by stand condition.

Most forest managers feel that the long-term solution to the WSBW problem lies in the silvicultural manipulation of the forest and they are asking for silvicultural guidelines to manage budworm-infested stands. They would like to know the effects of various types of cuttings, thinnings--both commercial and precommercial--stand density and species composition, and other stand and silvicultural practices on the impact by the WSBW. At this time, the influence of various silvicultural and/or forest management practices on either the biology and ecology of the budworm or the incidence of budworm damage to residual or regenerating stands is little known in Northern Rocky Mountain stands.

There are three times during the 1-year developmental period of the WSBW when the organism is mobile and when, either under its own control or indirectly controlled by micro-environmental conditions, it can disperse within and between forest stands. Since the tree is the substrate on which larvae feed, over winter, and pupate, and on which females mate and lay eggs, the tree and the condition of the stand in which the tree exists is closely related to and influences these life processes.

These studies were designed to determine that relationship between the forest, the stand and the tree, and these life processes. Specific studies of larval dispersal and adult behavior as related to stand conditions and silvicultural practices were initiated for at least three reasons:

1. Dispersal loss--We know from some studies that stand densities and crown closures are related to larval dispersal behavior, and hence dispersal loss. And we speculate that at other sites, species composition, tree height, as well as other stand factors, are also closely tied to larval loss through dispersal. And larval dispersal loss can be a significant factor in the population dynamics of the WSBW in a given forest or area.

2. Regeneration success--We suspect that the distribution and abundance of dispersing stage II larvae is very closely tied to seedling establishment and seedling development. We also suspect, and have some preliminary unpublished data indicating that the dispersal of stage I larvae is influenced by stand conditions and silvicultural practices, hence indirectly affecting seedling establishment and development.

3. Studies of larval and adult dispersal, especially as related to stand conditions and other abiotic and biotic factors, will provide data for improving sampling and for models to predict budworm population changes and resultant damage. Hence, studies of larval and adult dispersal can be integrated with, and contribute to, other studies as part of the WSBW R&D Program.

OBJECTIVES

Presented below are the overall, long-term objectives of this study, written with the understanding that this study would continue through the life of the Program. Also presented are the objectives or research tasks, planned for each of the three funding periods, 1978, 1979, and 1980.

Following the statement of each objective or planned task is presented a statement of research progress in, or toward, completing that objective.

Overall

Objective 1

To determine the influence of silvicultural practices on dispersal behavior and abundance of stages I and II of western spruce budworm larvae. Question: Can the manipulation of forest stands (i.e., silvicultural practices) that alters stocking density, species composition, and size class increase or decrease the number of dispersing stage I and stage II larvae reaching the ground (dispersal loss), or the manner in which they get there?

Progress

This overall objective was to have been achieved by measuring larval dispersal at nine intense study sites, in concert with a related CANUSA-funded study under the direction of Clint Carlson. During 1978 and 1979 we were able to get to only two of those sites, namely Lubrecht Experimental Forest (with four different cutting units) and Newman Ridge study area (with four clearcut units). Our objectives for those 2 years were achieved. However, the achievement of the overall objective is contingent on continued funding (through a research proposal prepared by Carlson and Fellin for FY 1981) to measure dispersal at the other seven intense sites each year through the rest of the Program.

Objective 2

To determine the influence of silvicultural practices on flight, dispersal, and ovipositional behavior of western spruce budworm adults. Question: Will the manipulation of forest stands cause male and/or female moths to avoid certain stands, attract them to others, or result in more or fewer eggs being laid on one species or size of tree compared to other host species of varying sizes?

Progress

This overall objective, too, was to have been achieved through measurements at nine study sites, as described above for the larval dispersal phase. During 1978 we measured local dispersal of adult males at two sites, Lubrecht and Newman Ridge. In 1979, we again measured male dispersal at these two sites as well as at three other intensive study sites--Chamberlain Creek (seedtree), Blue Mountain (clearcut), and Valley Creek (selection). Our objectives for these 2 years were achieved. In 1980, however, the Program elected to discontinue support of this adult behavior portion of the study, so the overall objective (including ovipositional patterns related to tree species and size) will not be achieved.

Objective 3

To determine the relationship of the dispersal behavior of western spruce budworm larvae and flight behavior of adults as influenced by silvicultural practices to the incidence of seedling establishment and development. Question: Will more or fewer seedlings become established or suffer more or less impact (damage) indirectly because of the direct influence of silvicultural practices on the behavior and abundance of dispersing larvae or the flight behavior of the adults?

Progress

This objective is inextricably tied to the study now funded and directed by Carlson and proposed to be continued by Carlson and Fellin in FY 1981. We have both larval and adult dispersal data and regeneration data for 2 years at one study site, Newman Ridge, and adult data and regeneration data for 1 year, 1979, at three other intense sites, Blue Mountain, Chamberlain Creek, and Valley Creek. The objectives for 1978 and 1979 were achieved.

With the discontinuance of the adult phase of the study, that portion of the overall objective will not be achieved. Moreover, if the larval dispersal phase of the study does not continue in FY 1981 and beyond we will have only a portion of our matrix filled and that aspect of the overall objective will not be achieved.

A progress report relative to overall objective #2, including data analysis for 1978 and 1979, was prepared by Carlson and Fellin on April 1, 1980 and forwarded to the Program April 18, 1980.

Objective 1

Assemble and analyze existing data on larval dispersal collected 1973 to present.

Progress

Prior to the onset of the CANUSA-West Program and the INT commitment and involvement in current WSBW research, the principal investigator conducted research on some aspects of dispersal of WSBW larvae as part of an INT Forest Residues R&D Program assignment. This past research has provided base and background data for the current CANUSA-West funded study. Moreover, it has provided dispersal data for use by other CANUSA-West funded researchers interested in dispersal behavior of WSBW larvae.

During this funding period we began transferring these dispersal data from field-lab data forms to a format which could be incorporated into a data processing system. Hence, the data assembly has begun, but the analysis was not started.

Objective 2

Prepare manuscript presenting techniques and procedures used to measure larval dispersal.

Progress

During the past few years nearly half a dozen researchers have investigated the dispersal of WSBW larvae, with varying objectives, and in different geographic locations. These investigators have "convergently evolved" at the same objectives--that is, measuring larvae dispersal--through various techniques and procedures.

Four of these investigators concurred that for the benefit of other researchers involved in the general area of WSBW dispersal that their respective and varied techniques and procedures be published.

A rough draft of a manuscript has been prepared by Dr. Dan Jennings, NE-Orono, describing the techniques and procedures used in Minnesota and Maine. During this funding period, I began incorporating procedures and techniques used in Montana since 1973. I also met with senior author Dr. Dan Jennings concerning layout, photos, and illustrations needed. I began, but did not complete, my portion of the manuscript.

Objective 3

Monitor and measure dispersal of stage I and II larvae in recent harvested stands silviculturally prescribed to selection cutting, clearcutting, overstory removal, and understory removal.

Progress

During the summer of 1978, we measured the dispersal of stage II larvae (the stage most significant to this study objective and also to study objective #2) at approximately 200 study plots in the above silviculturally treated areas and adjacent undisturbed stands at Lubrecht Experimental Forest.

Additionally, we monitored the dispersal of stage II and stage I (summer) larval dispersal also at Lubrecht Experimental Forest, at 50 sampling points from pre- to post-dispersal period for each of the two larval stages.

Though not part of this objective, we were also able, fortuitously, to measure the dispersal of stage II larvae at the Newman Ridge study area. At this area we measured spring dispersal at nearly 150 study plots in four clearcut units representing four aspects, and adjacent undisturbed forests.

Objective 4

Prepare additional larval dispersal traps and begin locating additional study areas.

Progress

In late January, 1979, we ordered the materials and hired additional temporary help to prepare additional larval dispersal traps to use in other study areas.

On February 7, 1979, the INT-WSBW research team met at the Missoula FSL with representatives of nearly a dozen federal, state, and private agencies to begin the process of selecting additional study areas.

Later, in mid-March the team met with other INT investigators, as well as other cooperators in the Northern Rocky Mountains, to coordinate activities including the selection of additional study areas.

This coordination of study area selection involved not only the dispersal study described herein but other Missoula-based CANUSA-funded studies.

Objective 5

Review existing data on adult behavior and dispersal, begin establishing procedures for population sampling and collecting baseline data.

Progress

During this period we began reviewing existing literature concerning adult behavior and dispersal. With the help and encouragement of Dr. Gary Daterman, Corvallis, Oregon, Forestry Sciences Laboratory, we began establishing procedures for sampling and monitoring the flight behavior of adult males. We were able to, tentatively at least, determine minimum plot center locations, concentration of the attractant to be used, frequency of examining and changing traps, and other logistical and procedural elements.

Technicians with the INT-WSBW study team designed an apparatus to support the Pherocon II traps, since in many of our study areas there were no trees from which traps could be suspended.

During this first season we were not only able to make progress on our procedures and sampling problems, but were able to gather considerable data at two study sites--Lubrecht and Newman Ridge--relative to the relationship of stand conditions-silvicultural practices and the flight and dispersal of adult males concerning: 1) treatment effect on adult males, 2) period of flight of adult males relative to date and prescription, 3) edge-effects of stands on flight, and 4) efficiency in the deployment of traps.

Time Period--Last Half FY-79 and First Half FY-80

Objective 1

Continue the analysis of existing data on larvae dispersal collected in 1973-1977 (pre-WSBW Program) and prepare review draft of manuscript based on these data.

Progress

During this period we concluded transferring these dispersal data to a data processing format. All data was punched on cards and placed in both the Washington State University computer and on the mini-computer at the Missoula Forestry Sciences Laboratory. Neither the analysis nor the review draft was begun during this period.

Objective 2

Complete and submit for publication a manuscript (co-authored with Dr. Dan Jennings, NE, Dr. Harold Batzer, NC, and Mark Houseweart, Univ. of Maine) presenting techniques and procedures used to measure larvae dispersal in Maine, Minnesota, and Montana.

Progress

The Montana portion of the manuscript is still not complete because of some delays in cartographic and illustrator time as well as other commitments of mine. INT illustrator, Bryan Owen, did complete three drawings although there are more to do.

Objective 3

Continue to monitor and measure dispersal of stage II larvae and flight behavior and dispersal of WSBW adults in recently harvested stands silviculturally prescribed to selection cutting, clearcutting, overstory removal, and understory removal.

Progress

Measurements continued in spring 1979 at Lubrecht but traps were decimated by domestic livestock. However, traps were redeployed, and we measured dispersal of stage I larvae in August of that year, so we were still able to get some data relative to stand conditions and larval dispersal that year.

We also measured stage II larval dispersal at five units at Newman Ridge and associated undisturbed forests, although measurements at this study site were not part of this objective.

As in the previous funding period, we also monitored the dispersal of both stage II and stage I larval dispersal at 50 sampling points from pre- to post-dispersal period.

Objective 4

Select two additional study sites where partial cuttings have been made and begin monitoring and measuring dispersal of stage II larvae and flight behavior and dispersal of WSBW adults in these stands.

Progress

Three, not two, additional study sites were selected--Blue Mountain (Clearcut), Chamberlin Creek (Seedtree), and Valley Creek (selection). However, the areas were not selected early enough in the year to allow us to measure stage II larval dispersal.

However, in August of 1979 we measured flight and dispersal of adults at these three new sites as well as at already established study areas at Newman Ridge and Lubrecht Experimental Forest.

Objective 5

Investigate the possibilities or alternative ways of measuring the local dispersal of adult females, and complete the review of existing data on adult WSBW behavior and dispersal.

Progress

The review of existing literature on adult behavior and dispersal was completed. We did not begin any investigations on ways of measuring local dispersal of adult females.

Time Period--FY-80

Our research proposal prepared and submitted in August of 1979 had seven research objectives (tasks) as listed below. We were not funded to continue this study--only to summarize and analyze data collected through the 1979 field season as described in the first three objectives listed below.

Objective 1

Complete the analysis of existing data on larval dispersal collected in 1973 - 1977 (pre-WSBW Program) and complete the review draft of manuscript based on these data.

Progress

At this time, neither the analysis nor the review draft of the manuscript have been completed.

Objective 2

Complete the analysis of 1978 and 1979 larval dispersal data (supported by WSBW Program).

Progress

During FY 1980, all larval dispersal data from 1978 and 1979 (as well as 1977 larval data from Lubrecht) was transcribed from data sheets, punched, and entered on both the Washington State University computer and the mini-computer at the Missoula Forestry Sciences Lab.

The statistical analyses of these data was completed in mid-September. These analyses and their interpretations are presented in the "Results" section of this report. These results and their interpretation will form the basis of a manuscript to be prepared concerning larval dispersal.

Objective 3

Summarize 1978 and 1979 data relative to local dispersal of adult males. Begin preparation of manuscript based on these preliminary investigations.

Progress

During FY 1980, all adult dispersal data collected in 1978 and 1979 was also transcribed, punched, and entered on both the Washington State University computer and the mini-computer at the Forestry Sciences Lab.

The statistical analyses of these data was completed in mid-October. These analyses and their interpretations are presented in the "Results" section of this report. These results and their interpretation will form the basis for a manuscript to be prepared concerning local flight and dispersal of WSBW adults.

Objective 4

Complete and submit for publication a manuscript (co-authored with Dr. Dan Jennings, NE, Dr. Harold Batzer, NC, and Mark Houseweart, Univ. of Maine) presenting techniques and procedures used to measure larval dispersal in Maine, Minnesota, and Montana.

Progress

See item #2 in first half FY 1980 objectives for progress on this objective. No progress was made in the last half of FY 1980, so the paper has not yet been completed. It is scheduled as a high priority item after October 31, 1980. Incidentally, this paper is based on the research of the four co-authors and is not "just a literature review" as one of the Program reviewers has suggested.

Objective 5

In concert with Dr. Clinton Carlson, select four additional intensive study areas where work can be extended in FY 1980.

Progress

Carlson and I did select four additional study sites as follows: Valley Creek #2 (selection); First Creek (clearcut); Second Creek (shelterwood); and Union Peak (seedtree). The selection of these four intensive study sites completes the matrix of seven intense sites, plus Lubrecht. We have eliminated (for now at least) two intensive sites at Newman Ridge because of a population collapse.

Objective 6

Monitor and measure dispersal of stage II larvae and adult males at the nine intense study sites.

Progress

This spring we measured larval dispersal at all of our intensive study sites (seven plus Lubrecht). The samples have been processed and the data is now stored on both the Washington State University computer and our Missoula Forestry Sciences Laboratory mini-computer. The bulk of this research was done with YACC students recruited and supervised by Leon Theroux. Processing of the samples was confounded this year with ash fallout which came down while the traps were in the field.

This is the first season we have both regeneration data and data on stage II larval dispersal from the same sample points at all of our intense sites. These data are not included in this report but will be included in subsequent reports.

CANUSA did not fund the research on dispersal and behavior of WSBW adults in FY 1980. As a result, no research could be done in this facet of the study.

Objective 7

Continue to investigate the possibilities or alternate ways of measuring the local dispersal of adult females.

Progress

Nothing was done in FY 1980. CANUSA did not fund this research.

DESIGN

In the original proposals, prepared in February of 1978, this dispersal study was designed very closely to a companion study aimed at determining how silvicultural manipulations can be used to ameliorate effects of the WSBW in both mature and immature forests. In that related study, the following major and secondary variables were to be included or at least be identified in the sampling matrix:

Major Variable Matrix

1. Forest Climax Series
 - Douglas-fir
 - Grand fir
 - Subalpine fir
2. Regeneration Cutting Systems
 - Clear Cutting
 - Shelterwood
 - Seed Tree
 - Group Selection
 - Single-tree Selection
3. Infestation Level
 - None
 - Moderate
 - Heavy
4. Unit Size

To obtain some degree of stratification, the following three size categories are identified; but in reality, unit size would likely be a continuum:

- < 1 acre
- 1-50 acres
- > 50 acres

Secondary Variables

1. Site Preparation Methods
 - Prescribed Burn
 - Scarified
 - None
2. Province
 - East slope of the Northern Rockies
 - West slope of the Northern Rockies

Considering only the major variables, we would have a factorial type design of 3 series x 5 systems x 3 levels x 3 unit sizes x 2 replicates, which if properly balanced would total 270 study sites. We knew that not all combinations of the above factors would exist nor that we could sample all of them if they did.

Selection of Study Sites

The overall design for this study called for the selection, from the above matrix, of nine study areas representing a gradient of stand conditions--stocking level, species composition, etc.,--from undisturbed stands to clearcut sites in the Douglas-fir and subalpine fir forest series.

These nine study areas (table 1) were selected in concert with Clint Carlson, who is currently responsible for the regeneration study mentioned above as originally proposed in February of 1978. Fellin and Carlson were to jointly use these nine study areas as intense study sites where insect and stand measurements were to be made annually for the duration of the program.

Table 1.--Nine intense study sites, and some of their attributes, to be used during the planned 5-year duration of the studies of larval and adult dispersal (study sites in common with intense study sites used by co-investigator Dr. Clint Carlson)

Stand Name	Stand No.	Acres	No. of Plots	Habitat Type	Treatment Type	Location
Blue Mountain	143	81	57	Douglas-fir	Clearcut	SES32 T13N R20W
Chamberlain	135	231	69	Douglas-fir	Seedtree	NWS20 T14N R13W
Valley Creek #1	126	50+	49	Douglas-fir	Selection	SES3 T16N R21W
Valley Creek #2	210	50+	50	Grand fir	Selection	NWS17 T16N R20W
First Creek	200	13	37	Grand fir	Clearcut	NWS15 T16N R25W
Second Creek	205	20	33	Grand fir	Shelterwood	NWS14 T16N R25W
Union Peak	215	30	49	Subalpine fir	Seedtree	SWS5 T12N R14W
Newman Ridge	25	28	41	Subalpine fir	Clearcut	SES25 T18N R29W
Newman Ridge	26	28	44	Subalpine fir	Clearcut	SES25 T18N R29W
Lubrecht	Sub-1	11	32	Douglas-fir	Selection	Sec. 14 T13N R15W
	Sub-2	16	45	Douglas-fir	Understory rem.	
	Sub-3	14	39	Douglas-fir	Overstory rem.	
	Sub-4	17	42	Douglas-fir	Clearcut	

These sites were chosen because in addition to providing the treatment prescription needed: 1) they allow relatively easy access in spring during larval dispersal; 2) they represent a variety of resource management ownership; and 3) they require a very minimum of time and expense in travel, while still satisfying our study selection criteria. Lubrecht Experimental Forest is included in this list as a tenth area. Entomological data has been taken there continuously since 1977 and regeneration data is being taken by other studies in RWU-1251.

Stands at Lubrecht and Newman Ridge were selected in 1978, Blue Mountain, Chamberlain, and Valley Creek #1 were selected in 1979, and the remaining four were selected in 1980.

Both entomological and regeneration data were collected at Newman Ridge in 1978 and 1979. However, WSBW populations at those two study sites have "collapsed" so we have, for now at least, eliminated these two stands leaving us with seven intense study sites, plus Lubrecht.

Sampling Design and Plot Layout

At each of the intensive study areas, a series of sampling points was laid out so as to grid the area, regardless of the shape of the cutting unit or the silvicultural treatment. We determined that in order to achieve the objectives of the sampling procedure (determine treatment effect, edge effect, size of unit) the plots had to be systematically gridded as opposed to double 90° transects across the units.

Our sampling at Lubrecht and Newman Ridge in 1978 and 1979 was, by plan, intense; we intended to oversample. As we had originally planned, and coincident with the Program's concern for our sampling intensity, we carefully and critically evaluated (in concert with Gayle Yamasaki, INT Missoula FSL statistician) both the layout of our plots and the number of samples needed per area. Based on these detailed statistical analyses, we determined that:

1. In the study areas where larval dispersal was measured in FY 1979 (Lubrecht and Newman Ridge), the number of samples could be reduced by 50 percent without sacrificing the accuracy of estimating the population parameters.

2. We could project the need for a minimum of 60 sampling points for each of the nine intense study sites--50 points within the unit and ten points on the periphery as controls. We relaxed this for First Creek Stand #200 and Second Creek Stand #205 because of the smaller size of those stands.

Measurements Made

To measure both larval and adult dispersal and/or flight, we deployed a series of traps in the forest well before the dispersal/flight period began. These measurements were made at all of the sampling points in those stands and in those years as described in the following section.

DISPERSAL OF LARVAE

Field

The sampling unit for measuring larval dispersal consisted of a piece of 3/8 inch exterior plywood measuring 45 x 60 cm, one side of which was covered with a piece of heavy-duty coated butcher-wrapping paper (coated side up). To the coated side of the paper was applied a layer of tack trap using a linoleum glue spreader to insure an even, thin coating. A border remained uncoated so the sticky sample area was about 2 500 cm² or $\frac{1}{4}$ m².

Traps were transported to the field in boxes also constructed of 3/8 inch plywood, each of which held eight traps. The box was provided with cleats or runners on which the traps were slid in and out, and which kept the traps from adhering to one another. The boxes were used to transport the traps to and from the field plots, and also served as storage for traps.

Traps were set out in the field in late April-early May, well in advance of the first spring dispersing larvae. Three plastic pipe "stakes" were driven into the soil near the plot center. The top of each stake protruded through the trap in predrilled holes and a nail or cotter pin was slipped through a hole drilled in the stake 5 cm from the top to prevent the trap from sliding down. The affair was so placed that on slopes, the edge of the trap nearest the sidehill was at least 30 cm above the ground. All traps were so positioned that they sloped to allow water to run off the sticky surface. The traps were examined periodically to: 1) remove any sticks, limbs, or other debris that may have fallen on the traps; 2) check larval deposit; and 3) repair or replace any traps which may have been damaged by animals. A $\frac{1}{2}$ -inch hardware-cloth cover was placed over the traps and the protruding stakes to prevent trapping of birds and rodents.

As soon as the spring dispersal period was over (determined each year by monitoring with extra traps), the traps were picked up and transported in the boxes to the Missoula Forestry Sciences Lab. There they were stored at 34° F in a walk-in cooler to retard deterioration of the material pending examination of the traps.

Laboratory

At the laboratory, the tack-trap coated paper on each trap was cut into six equal-sized rectangles to facilitate examination. Each rectangular sample was placed on a similar sized rectangular piece of $\frac{1}{4}$ inch plywood which was then placed on a counting board designed so that grid lines were superimposed on the sample. The entire affair was then examined by moving the counting board back and forth under a dissecting microscope. The number of larvae on each sample was tallied. Also all other associated invertebrates of interest were counted or saved, after which the samples were discarded.

At times (i.e., in 1979 when cattle destroyed most of the traps at Lubrecht), we were able to get all or some of the spring dispersal traps examined soon after they were brought in from the forest. When we were able to do this, we redeployed all or some of the traps to measure summer dispersal of stage I larvae. In these cases, the traps were put out the last week of July and picked up and returned to the laboratory when the summer hatching period was over. The summer dispersal period has two features which distinguish it from spring dispersal: the larvae are instar I, rather than II, and they originate from eggs laid on the foliage rather than from overwintering sites. Both of these features could influence dispersal characteristics.

ADULT FLIGHT BEHAVIOR

Field

To measure adult flight behavior we used sticky-coated traps that were placed in the forest before the adult flight period and picked up afterward and returned to the laboratory.

In 1978, the traps, or sampling unit, were standard Pherocon II traps available commercially from Zoecon Corporation. Additional adhesive, generally tack trap, was applied to each trap to supplement that adhesive applied by the manufacturer.

In the forest, the traps were mounted atop a seven-foot pole which was driven in the ground. We feel that this was better than suspending the traps from tree limbs for several reasons, including: 1) the trap is kept upright, does not blow in the wind, and rain is less likely to enter the trap; 2) it randomly excludes the effect of the tree on trap catches; and 3) in some cutting units (clearcuts) there are no trees from which to suspend traps. Just prior to mounting the traps atop the poles, each trap was baited with a 0.01 concentration of (E)-11-tetradecenal, the sex attractant for the WSBW, supplied by researchers at the Corvallis, Oregon, Forestry Sciences Laboratory.

While in the forest, traps were examined periodically and those traps that became "filled" with males were replaced (the attractant from the "full" trap was placed in the replacement trap).

The same procedure was followed in 1979 except that the traps were fabricated from two-quart milk cartons, now a standard sampling unit being used by other investigators in the western United States.

As soon as the adult flight period was over (determined either by observation or by putting out extra monitor traps), the traps were picked up and transported to the Missoula Forestry Sciences Lab.

Laboratory

When the traps were brought in from the forest, they were stored at 34° F in a walk-in cooler to retard deterioration of the material, pending examination of the traps. When examined, each trap was cut apart and the number of adult WSBW males in each trap counted and recorded. The sample traps were then discarded.

Data Collection

The basic data collected in 1978 and 1979 was an expression of: 1) the number of dispersing larvae reaching the ground expressed as the number of dispersing larvae per unit area, and 2) an expression of the number of adult males caught in the traps expressed as the number of adult males per trap. As far as this study is concerned, no other measurements were made at the sampling points. However, Carlson's study, with which this study is closely integrated, calls for the sampling points, which are common to both studies, to serve as centers for 1/300th acre plots where he is measuring: site variables, regeneration characteristics, WSBW defoliation, and other damaging agents.

The following larval and adult dispersal data were collected during 1978 and 1979. From 1978 we have larval dispersal data from all four stands at Lubrecht and from stands 25 and 26 at Newman Ridge (plus two other clearcut units). In 1979 we have larval dispersal data from all four stands at Lubrecht and from stands 25 and 26 at Newman Ridge (plus three other clearcut units). We have adult dispersal data in 1978 from all units at Lubrecht and stands 25 and 26 at Newman Ridge (plus two other clearcut units). In 1979 we measured adult dispersal at all four Lubrecht stands, at stands 25 and 26 at Newman Ridge, and at Blue Mountain, Chamberlain Creek, and Valley Creek #1. In 1980 we measured larval dispersal at all intensive sites--except Newman Ridge 25 and 26--and at Lubrecht. These data, however, are not included in this report. No data on adult dispersal was taken in 1980.

Data Analysis

For the 1978 and 1979 research, the two overall null hypotheses being tested are that regeneration cutting systems have no influence on either 1) dispersal pattern of stage II larvae, or 2) flight behavior or local dispersal of adult male budworm.

These hypotheses will be tested using: analysis of variance, analysis of covariance, Duncan's Multiple Range Test, and chi-square. Since data collected with both larval dispersal and adult flight was expressed as numbers per unit area or per trap, transformations have been considered necessary to bring the response closer to normal. Some data was transformed using the square root transformation for discrete data where:

$$x^1 = \sqrt{x + 3/8}$$

Under the assumption that this study was to have continued, or will be continued (see Carlson-Fellin proposal for FY 1981), and integrated with the data collected in the regeneration study directed by Carlson, it was planned that the data would be statistically interpreted using techniques of multiple regression and covariance analysis with the assumed general model as:

$$y = a + b_1 x_1 + b_2 x_2 + b_i x_i + b_j x_j + e$$

Independent variables will include forest climax series, residual basal area, unit size, distance to source of dispersing larvae and invading moths, and egg and larval density and incidence of defoliation in the surrounding stands. Dependent variables will include numbers of larvae and adults caught in traps. Analysis covariates will include intrinsic site variables such as slope, aspect, physiography, etc.

Using this generalized model, the coefficients for the variables will be computed, their significance assessed, and with the data from Carlson's study we can: 1) translate study results into generalized recommendations for silvicultural prescriptions, and 2) incorporate our data through this model into the ultimate western spruce budworm model to be developed by the Program.

RESULTS AND DISCUSSION

Dispersal of Stage II Larvae

LUBRECHT EXPERIMENTAL FOREST

Throughout this report, I am including all of my 1977 data on spring dispersal of stage II larvae at Lubrecht since these data, though collected pre-CANUSA, are needed to most effectively interpret the data collected in 1978 and 1979.

Main Effect of Harvest Treatment

When the study area at Lubrecht Experimental Forest was selected and the four cutting blocks laid out in 1976, all investigators involved, including myself, insured that the study area represented a homogeneity of as many physical, geographic, and stand factors as possible--terrain, slopes, aspects, tree species, stand composition, etc. Yet the incidence and pattern of dispersing stage II larvae in spring 1977 as shown by means and ranges in numbers indicated some heterogeneity in the stand structure and species composition in this undisturbed forest. The mean number of larvae trapped in the four stands to be harvested and the control area varied from 41.2 larvae/trap in the planned selection (SEL) cut¹ to 78.4 larvae/trap in the stand where the OR was to be removed (table A-1).²

One might be tempted to attribute the fewest number of larvae in the SEL cutting area prior to harvesting to the fact that the unit had a somewhat higher incidence of ponderosa pine than any of the other three planned cutting units. However, the mean number of larvae dispersing in the planned SEL unit was for all practical purposes the same as in the undisturbed stand, which was quite comparable, species-composition-wise, to the other three planned cutting units.

¹Throughout this report abbreviations may be used for cutting units as follows:

<u>Cutting unit or harvest treatment</u>	<u>Abbreviation</u>
Selection	SEL
Overstory removal	OR
Understory removal	UR
Clearcut	CC
Control	CON

²Throughout this report Appendix Tables will be referred to as tables A-1, A-2, etc.

Between 1977 (preharvest) and 1978 (first-year postharvest), all units except the SEL showed decreases in the incidence of dispersing stage II larvae, the decreases varying from -28 percent in the CC to -59 percent in the OR (table A-2). Decreases in the UR and CON were nearly the same at -42 and -40 percent, respectively. This 40 percent decrease in the undisturbed forest perhaps indicates a similar percentage decrease in WSBW populations throughout the study area. If so, the decreases in the other cutting units should not be surprising. Unexplained, however, is the 4-percent increase in the SEL, unless the preponderance of ponderosa pine is involved.

One would have expected--since dispersing stage II larvae originate from overwintering sites on the boles (primarily) and limbs (secondarily) of host trees--that the number of larvae dispersing into the cutting units in 1978 would be related to the severity of the treatment (cuttings were made in the summer and early fall of 1977). That is, the more severe the treatment (the more trees removed), the fewer larvae one would expect to be dispersing in the cutting unit. However, decreases in the number of dispersing larvae between 1977 and 1978 are inconsistent with the severity of the treatment.

In 1979, the number of samples were decreased because livestock damaged most of the traps that spring (table A-3). However, all units except the overstory removal had higher populations in 1979 than in 1978. Moreover, with the exception of the selection cut in 1977 and the overstory removal in 1979, the number of dispersing larvae reaching the ground (trapped) was higher in all of the cutting units in both 1978 (table A-2) and 1979 (table A-3), compared to the respective controls.

In both 1978 and 1979, considering the severity of the treatments, one would have expected a wider range and a closer relationship in the mean values between treatments. In other words, one would have expected the fewest number of larvae dispersing in the CC, which was the most drastic treatment, and the most larvae dispersing in the UR which was the least drastic treatment, with the OR, SEL, and CON somewhere in between.

To further interpret my hypotheses, and to elaborate on my above interpretations based only on means, we analyzed the 3 years of data from Lubrecht using the following statistics: chi-square (x^2), Analysis of Variance (ANOVA), Covariance Analysis (ANOCOVA), and Duncan's Multiple Range Test (DMRT). No chi-square tests were made of the 1979 data because the majority of the sampling units were destroyed.

There was a heterogeneous distribution of dispersing stage II larvae in all four treatments and the control both prior to harvest, in 1977, and in the first postharvest year, 1978, as shown by the chi-square values (all highly significant) in the following tabulation:

<u>Stand treatment</u>	<u>Year</u> <u>chi-square</u>	
	<u>1977</u>	<u>1978</u>
Selection	203.1	94.8
Understory removal	718.2	419.2
Overstory removal	490.7	173.0
Clearcut	239.4	528.4
Control	145.0	58.9

Because of this heterogeneity, all data were transformed using the square root transformation $\sqrt{x + 3/8}$, as already discussed in the "Data Analyses" section.

Although chi-square analyses were not made on the 1979 data, it is likely that larval dispersal patterns were heterogeneous in 1979, just as they were in 1977 and 1978.

Stand differences by year.--We found a highly significant difference between stands in the number of dispersing stage II larvae within each of the 3 years of the study (table 2).

Table 2.--Partial ANOVA of the number of dispersing stage II larvae between firestands in each of 3 years, Lubrecht Experimental Forest

Year	Source of variation	df	Mean square	F	PR>F
1977	Stand	4	31.8	12.9**	0.0001
	Error	165	2.5		
1978	Stand	4	7.5	6.5**	0.0001
	Error	163	1.2		
1979	Stand	4	13.7	8.6**	0.0001
	Error	92	1.5		

**Values highly significant.

Duncan's Multiple Range Test was made on the data for each of the 3 years. The test for variable larvae-1977 is as follows:

<u>Planned stand treatment</u>	<u>Number samples</u>	<u>Number larvae</u>	<u>Grouping¹</u>	
Overstory removal	37	8.7		A
Understory removal	44	7.3		B
Clearcut	43	6.8	C	B
Control	15	6.3	C	B
Selection	31	6.3	C	
df = 165		Mean square = 2.46412		

¹Means with different Grouping letters are significantly different (Alpha level .05).

From the test above, one can observe that populations of dispersing larvae in the:

1. OR are significantly higher than those in all other treatments.
2. UR are significantly higher than those in the SEL, but not those in either the CC or CON.
3. SEL are significantly lower than those in the OR or UR, but not those in either the CC or CON.

Since these units (stands) had not yet been cut in 1977, the above analysis serves to point out the variability in WSBW populations that existed in that undisturbed <100-acre experimental area.

The DMRT for variable larvae-1978 shows a somewhat similar configuration of groupings but with different stands in the groups as follows:

<u>Stand treatment</u>	<u>Number samples</u>	<u>Number larvae</u>	<u>Grouping¹</u>	
Selection	32	6.5		A
Clearcut	39	5.7		B
Understory removal	43	5.6	C	B
Overstory removal	39	5.5	C	B
Control	15	4.9	C	
df = 163		Mean square = 1.16754		

¹Means with different Grouping letters are significantly different (Alpha level .05).

The 1978 DMRT above shows that populations of dispersing larvae in the:

1. SEL are significantly higher than those in all other treatments.
2. CC are significantly higher than those in the CON, but not those in either the UR or OR.
3. UR, OR, and CON are not significantly different from one another.

There are at least three interpretations that can be made based on the relationships shown above in this first posttreatment year:

1. Larval populations in both the SEL and CC are significantly higher than in the CON. The preponderance of ponderosa pine in the SEL unit may explain why this unit has a higher incidence of dispersing larvae than any of the other four units.
2. One would not expect dispersing larval populations in the CC, UR, and OR to be insignificantly different, since these three silvicultural prescriptions are very dissimilar.
3. Opening up of the stands in all four treatments may explain why dispersing larval populations are higher in all four treatments than in the CON. However, if this were the case, one would expect populations dispersing into the CC to be lowest, and those in the UR to be highest; this is not the case.

In 1979, the second posttreatment year, the DMRT for variable larvae shows some changing relationships compared to both 1977 and 1978, as follows:

<u>Stand treatment</u>	<u>Number samples</u>	<u>Number larvae</u>	<u>Grouping¹</u>
Clearcut	10	7.5	A
Understory removal	24	7.3	A
Selection	22	7.2	A
Control	28	6.0	B
Overstory removal	13	5.4	B
df = 92		Mean square = 1.58867	

¹Means with different Grouping letters are significantly different (Alpha level .05).

The above test indicates that dispersing larval populations are not significantly different between the CC, UR, and SEL, but in all three of these stands populations are significantly higher than those in the OR and CON where populations are not significantly different from one another.

There appears to be little consistency in the effect of stand treatment on the incidence of dispersing larvae in the two seasons following the cuttings. It must be pointed out that the degrees of freedom in 1979 is only 92, compared with 163 and 165 in 1978 and 1977, respectively, and that the numbers of observations ("N" values) in 1979 are considerably lower in all stands compared to either 1977 or 1978. These changes in numbers reflect the decimation of the sample traps by cattle in 1979. This reduced sample size in 1979 could conceivably affect analyses of data for that year.

Year differences by stand.--Generally, there were significant differences in the incidence of dispersing stage II larval populations between the years in all of the four stand treatments. The mean number of dispersing larvae caught per trap in 1978 was significantly lower than the number of dispersing larvae trapped in 1977 in all stands except the SEL (table A-4). As mentioned earlier, there could be something about the nature of the SEL unit--perhaps the higher incidence of ponderosa pine--that explains why populations in that unit remained static between 1977 and 1978, while populations in all other stand treatments, as well as the control, decreased in 1978. Other than the SEL unit the reductions in the incidence of dispersing larvae between 1977 and 1978 may reflect an overall regional or local downward trend in WSBW populations, especially since the populations in the controls decreased as well.

In all four stand treatments, populations of dispersing larvae were highly significantly different between the 3 years. Population changes in the CON were also significant, but less so than in the treated areas (table A-5). Again this may indicate that the silvicultural treatment, regardless of how "severe," or how many trees are removed, modifies the forest environment sufficiently to influence the dispersal pattern of these spring dispersing larvae, compared to their dispersal characteristics in the undisturbed forest.

However, the effect of stand treatment on these dispersing larvae appears to be unexplainable and inconsistent with what one would expect, based on the nature and severity of the prescribed silvicultural treatment. As indicated in the DMRT (table A-6), populations in 1979 varied by treatment, as compared to populations in 1977 and 1978. In the UR, CC, and the CON, populations in both 1977 and 1979 were not significantly different, but were significantly higher than in 1978. In the SEL, populations in 1979 were significantly higher than either 1977 or 1978. In the OR, dispersing larval populations were stable and not significantly different between 1978 and 1979, but in both years were significantly higher than in 1977.

Notwithstanding the inconsistencies noted above, it appears that the environment created by both the SEL and OR treatments influences the dispersal of stage II larvae, perhaps more so than either the CC or UR. A significant treatment effect apparently occurred in the OR, where populations decreased significantly, but remained stable in the 2 years following the cutting. In the selection, populations remained stable the first year after treatment, but increased significantly the second year; no treatment effect is apparent in the UR or CC where population trends were similar to the controls.

Further support for the influence of the SEL treatment on dispersing larvae comes from portions of three ANACOVA (table A-7) and its associated DMRT (table A-8), showing the effects of treatment in 1978 and 1979, with 1977 and 1978 as covariates. The ANACOVA shows a highly significant effect of stand treatment on dispersing larvae in both 1978 (with 1977 as covariate) and in 1979 (with both 1977 and 1978 as covariates). In 1978, the mean number of larvae trapped was significantly higher in the SEL than in any of the other cutting units or the CON (table A-8). Moreover, means in the CC, UR, and OR were not significantly different from those in the CON.

In comparing the ANOCOVA in the DMRT in the top of table A-8 to the DMRT on page 23, one can see that the stand rankings remain the same, but that the ANOCOVA eliminated the groupings of CC=OR=UR, and UR=OR=CON, and also eliminated the significant difference between CC and control.

The covariance analysis of larval dispersal in 1979 using either 1977 larvae (table A-8, center) or 1978 larvae (table A-8, bottom) as the covariate, did not change the rankings or the groupings of stands (treatments) as presented in the DMRT on page 24.

In summarizing this section on the main effect of stand treatment on dispersing stage II WSBW larvae, there are at least three rather significant interpretations or comments that should be made:

1. It appears that 1 year following treatment the SEL unit has some features that affect larval dispersal differently than any of the other treatments (including the CON), and these features of the SEL have some weak affinities with the CC and UR as shown in the DMRT on page 23.
2. These four cutting units were logged in the late summer and fall of 1977 when moths were flying and mating, females were ovipositing, and larvae were hatching from eggs and searching out overwintering sites. The removal of all or part of the stand in the respective cutting units no doubt seriously affected overwintering stage II larval populations--hence their dispersal pattern the following spring. It seems, then, that dispersal patterns in the spring of 1978 could be seriously confounded with the affects of the logging the previous late summer and fall. This may explain the disparity in the results of the ANACOVA in 1978 and 1979, using 1977 as the covariate (table A-8).

3. Once again, as mentioned before, the smaller data base we had in 1979, because of the loss of so many traps to cattle damage, could influence the analyses and their interpretations.

Edge Effect of Harvest Treatment

Other than the main effect of harvest treatment, as discussed in the preceding section, the edge effect of harvested stands is no doubt the second most significant stand parameter influencing dispersal of WSBW larvae in managed forests. In all subsequent analyses of edge effects of treatment, larval dispersal traps were sorted out and the data classified into one of three positions: center of cutting unit, edge of cutting unit, and control.

At the Lubrecht Experimental Forest study area, all of the four cutting units have a large "reservoir" of overwintering larvae in the undisturbed stands surrounding each cutting unit. In essence, any movement or dispersal of these overwintering larvae from this edge, or reservoir, into the cutting units constitutes an edge effect. However, each cutting treatment has a feature, or features, that can "dampen" or influence this edge effect, as follows:

Clearcut--No standing trees in the unit to intercept any lateral dispersal from the edge into the cutting unit, nor any crop trees in the unit from which larvae can disperse from overwintering sites.

Overstory Removal--No overstory trees in the unit from which larvae can disperse, but substantial numbers of understory residual trees capable of intercepting larvae dispersing laterally from overstory edge trees.

Understory Removal--Substantial numbers of overstory residual trees from which larvae can disperse, but few understory trees to intercept vertically dispersing larvae.

Selection--A combination of OR and UR with some overstory residual trees from which larvae can disperse, and some understory trees where vertically dispersing larvae can be intercepted. However, treatment resembles UR more than OR.

Control--A large reservoir of overwintering WSBW larvae in overstory trees with substantial understory to intercept vertically dispersing larvae.

1977.--One is reminded that no cutting had yet been done at the time of spring dispersal of stage II larvae in 1977, so no edge effect, per se, should have been expected. In the SEL, UR, and CC units planned for cutting, no significant differences in the number of spring 1977 dispersing larvae (i.e., no edge effect) were indicated by either the ANOVA (table A-9) or the DMRT (table A-10).

In only one planned cutting unit, the OR, was a significant difference indicated between center, edge, and control (table A-9). The DMRT in table A-10 shows that in the planned OR in 1977, significantly fewer larvae dispersed in the CON than in the portion of the stand that was to be either the edge or center of the OR cutting unit; dispersing larval populations in the latter two areas were not significantly different from one another.

1978.--There were some indications of edge effects in 1978, the first postharvest year, when one would have expected some effect of treatment edge on dispersing larval populations. However, our more sensitive analyses indicate that edge effects are insignificant in 1978.

In both the SEL and OR, an ANOVA shows highly significant differences between the numbers of larvae dispersing in the edge and center of the units and the adjacent CON; no such differences are evident for the CC and UR (table A-11). These relationships are supported by the ANOCOVA as shown in table A-15.

The DMRT (table A-12) shows where the differences lie in the SEL and OR. No edge effect is indicated in the SEL where larval populations between center and edge are not significantly different from one another, but both are significantly different from the CON; essentially this is a treatment effect discussed earlier. According to the DMRT, the OR is the only stand in which an edge effect on dispersing larvae was evident in 1978. In this case, means along the edge of the stand are significantly higher according to this test than those either in the center of the unit or in the CON.

In the UR, the number of larvae dispersing in the center of the unit are not significantly different from those dispersing at the edge, while numbers dispersing at the edge are not significantly different than those dispersing in the adjacent CON. Both of these similarities indicate no edge effect. Moreover, the means in the control are significantly lower than means in the center of the unit, just the opposite of what would be an edge effect.

In summary, our most sensitive test, the DMRT of the ANOCOVA (table A-16), indicates that there are no significant edge effects of any of the four stand treatments on the dispersal pattern of stage II larvae in 1978 at Lubrecht. The refined DMRT analysis in table A-16 shows no significant differences in means between the edge, center, or control, in both the UR and the CC. The relationships in the SEL and OR are the same in that: 1) means are not significantly different between the control and edge, nor between edge and center; but 2) means in the control are significantly higher than those in center of both the selection and the OR.

1979.--In 1979, because of the loss of so many traps, particularly in the overstory removal and clearcut, we were only able to test for edge effects in the selection and UR stands.

Significant differences in the means of dispersing stage II larvae between the center, edge, and controls in both the SEL and OR are indicated by the ANOVA (table A-13), while the DMRT (table A-14) shows wherein the differences lie. In both the SEL and the UR units, the means of dispersing larvae are not significantly different between the center and the edge of the stand. But, in both cases, populations of dispersing larvae in the CON are significantly lower than means at either center or edge within the stand. This shows a treatment effect, a fact that we have already established earlier in the report, but no edge effect.

The more sensitive ANOCOVA for edge effect of dispersing larvae in 1979, with 1978 as covariate (table A-17), and its associated DMRT (table A-18), support and refine the conclusions drawn from the ANOVA as shown in tables A-13 and A-14. The ANOCOVA indicates a highly significant difference in the SEL between edge, center, and control with dispersing larval populations significantly lower in the CON than in either the center or edge of the cutting unit--essentially a treatment effect, but no edge effect. The ANOCOVA shows no significant differences in the mean number of dispersing larvae between the center, the edge, and the controls in the UR.

The small sizes of the stand treatments (15 acres) and the relatively moderate relief of the terrain on which the cuttings were made, are probably the two factors responsible for the general absence of an edge effect of stand treatment on the dispersal of stage II larvae from the adjacent undisturbed stands into the cutting units. We have some data from other sites that indicate edge effects do exist in larger cutting units or in stands where cuttings are made in forests growing on steeper slopes.

NEWMAN RIDGE STUDY AREA

As stated in the data collection section on page 18, we collected stage II larval dispersal data from four clearcut units in 1978, and from five clearcut units in 1979 at the Newman Ridge study area. Two of these, stands South-1 and East-3, were included in our original design of nine intensive study sites.

Two circumstances developed that affect the analysis and interpretation of data from Newman in 1978 and 1979: 1) No control data were collected in 1978, and 2) In 1979, WSBW populations were at extremely low levels; consequently few larvae dispersed, and on the majority of our traps most counts were zero. Because of this, no analysis can be made of, nor interpretations from, the 1979 data. Therefore, results presented below for 1978 and 1979 will consist of summary tables for both years, and chi-square tests, ANOVA, and DMRT, to determine treatment and edge effects in 1978.

Main Effect of Clearcut Treatment

The mean number of larvae reaching the forest floor in 1978 and 1979 at the Newman Ridge clearcuts are shown in table A-19. It is evident from the means in table A-19 that not only were populations in 1978 relatively low--especially when compared to those at Lubrecht in the same year (table A-2)--but that WSBW populations collapsed at Newman Ridge between 1978 and 1979. In either of the treatment or the control, no dispersal trap collected more than two larvae in 1979.

In spite of the low WSBW populations and the few larvae that dispersed in 1979, in at least three units--East-1, East-3, and South-1--considerably fewer larvae dispersed into the clearcut units than in the adjacent undisturbed forests. In South-3, however, twice as many larvae reached the ground in the clearcut as in the adjacent forest, while in North-1 the distributions in the treatment and control were the same.

The mean number of stage II larvae (caught per trap) dispersing in 1978, were unequally and heterogeneously distributed, particularly in units North-1 and South-1, as shown in the following chi-square tests:

<u>Unit</u>	<u>Chi-square</u>
East-1	22.8*
North-1	101.3*
South-1	60.3*
East-3	31.4*

*Significant at 5 percent level.

Because of this heterogeneity, all 1978 data were transformed according to the square root transformation, $\sqrt{x + 3/8}$, as already discussed in the Data Analysis section.

The mean number of larvae dispersing in 1978 were highly significantly different between the four units studied (table 3).

Table 3.--Partial ANOVA of the number of dispersing stage II larvae in four units in 1978, Newman Ridge study area

Source of variation	df	Mean square	F	PR>F
Stand	3	1.97	4.37**	0.0062
Error	95	0.45		

**Highly significant.

The difference in the number of dispersing larvae between the four clearcuts is partitioned by the DMRT as follows:

<u>Stand</u>	<u>Unit Number</u>	<u>Number samples</u>	<u>Number larvae</u>	<u>Grouping¹</u>
East-3	26	32	2.7	A
North-1	24	20	2.7	A
East-1	23	24	2.5	A
South-1	25	23	2.1	B
df = 95		Mean square = 0.449558		

¹Means with different Grouping letters are significantly different (Alpha level .05).

Although the means are not widely separated, the DMRT indicates that the numbers of larvae dispersing into unit South-1 are significantly less than the mean numbers dispersing into the other three, which are not significant between them. Although there are no apparent or measured features about clearcut South-1 or the undisturbed forest surrounding it to explain why fewer larvae dispersed into it compared to the three other clearcuts, the influence of aspect and/or related thermal patterns could be responsible.

Edge Effect of Clearcut Treatment

As mentioned earlier, no data were collected at Newman in 1978 in the controls or undisturbed stands surrounding the four clearcuts, so our analyses of edge effects compare only the mean number of larvae dispersing to traps on the periphery of the clearcuts, compared to traps in the centers of the units. Since we had no measurements from the controls, we could not therefore measure the full effect of edge.

Unit #25, South-1, is the only clearcut of the four where a significant difference is shown between the number of larvae dispersing at the center and edge of the cutting unit (table A-20). Although in all four clearcuts, the mean number of larvae dispersing around the edge of the cutting unit is higher than the mean number in the center, the DMRT (table A-21) shows that only in unit South-1 is this edge effect significant.

Why, out of the four units, should South-1 show an edge effect? Perhaps one should not expect an edge effect in either North-1 or East-3. North-1 is nearly completely surrounded by other clearcuts, so there is really no timber wall with which to create an edge effect. East-3 is nearly completely surrounded by timber, but the unit is fairly small so the edge and center are not very discrete, and the effect of the surrounding timber would essentially affect the entire unit.

One would have expected an edge effect in both South-1 and East-1. Both of these two clearcuts are very similar, except for aspect, in that they are rectangular with the long axis on the contour and both bordered by dense timber on their lower sides, only marginally timbered at the ends, and with no timber along the upper edge of the unit. Perhaps the only explanation for an edge effect in South-1 and not East-1 in 1978 would be either the prevailing and/or thermal winds at the time of maximum larval dispersal.

Dispersal of Adult Males

As mentioned in an earlier section on Data Collection, we have adult dispersal data for: 1) five stand treatments at Lubrecht Experimental Forest for both 1978 and 1979; 2) at the Newman Ridge study area for four units in 1978 and two units in 1979, and 3) for three other study areas in 1979. The data and analyses will be presented in that order.

LUBRECHT EXPERIMENTAL FOREST

Our studies of adult dispersal behavior at the Lubrecht study area did not begin until the summer of 1978, which was the first year following the cuttings. We do not, therefore, have adult dispersal data for 1977, the year prior to stand treatments.

Moth Dispersal at Lubrecht in 1978

There was a very close relationship between the "severity of treatment" and the number of adult males trapped in 1978--the more "severe" the treatment, the fewer moths were caught (table A-22). In the UR unit, which of all four cuttings is most similar to the CON, we trapped about the same number of moths as in the undisturbed forest. In the CC, where essentially no trees remained standing, the fewest number, by far, of moths were caught. Catches in the SEL and OR were intermediate between the CC and the UR and CON. Based on the severity of treatment, we would have expected more moths to have been caught in the SEL than in the OR since the SEL more closely resembles the UR and CON.

It is not unexpected that there were many more moths trapped in the UR than in any of the other three cutting units. Female adults prefer overstory and often silhouetted trees for oviposition, so they would be inclined to avoid the environmental and stand conditions created by the other three treatments. Since males are being attracted to the females, they (males) would be less numerous where there are fewer females (so what's new?).

The wide ranges in the minimum and maximum numbers of moths caught (table A-22) in all five stands indicate a heterogeneous distribution which is supported by the chi-square analysis:

<u>Stand treatment</u>	<u>Chi-square in 1978**</u>
Selection	423.5
Understory removal	835.4
Overstory removal	1069.7
Clearcut	348.6
Control	325.7

**All values highly significant.

Because of this heterogeneity in the distribution of adult males, all data were transformed according to $\sqrt{x + 3/8}$, the transformation already used in the heterogeneous larval data.

Main effect of treatment.--There was a highly significant difference in the number of moths caught between treatments (table 4).

Table 4.--Partial ANOVA of the number of WSBW adult male moths caught at five stands in 1978, Lubrecht Experimental Forest

<u>Source of variation</u>	<u>df</u>	<u>Mean square</u>	<u>F</u>	<u>PR>F</u>
Treatment	4	349.9	89.8**	0.0001
Error	169	3.9		

**Highly significant.

The DMRT of the ANOVA (table 4) shows differences as follows:

<u>Stand treatment</u>	<u>Number samples</u>	<u>Number moths per trap</u>	<u>Grouping¹</u>
Control	15	12.3	A
Understory removal	45	12.1	A
Overstory removal	39	8.8	B
Selection	32	7.8	C
Clearcut	43	4.8	D

df = 169 Mean square = 3.89505

¹Means with different Grouping letters are significantly different (Alpha level .05).

As shown in the DMRT, the number of moths caught in the CON and the UR are not significantly different, but moth catches in both of those units are significantly higher than in any of the other three. Moreover, catches in each of the other three units are also significantly different from one another with the $OR > SEL > CC$. As mentioned above, with the preference of female moths for the taller overstory trees for oviposition, one would expect to trap the most males in those least drastic cutting units; and with the exception of the unexpected transposition of the OR and SEL, this is what happened. Again, the higher incidence of ponderosa pine in the SEL may have influenced some moths to avoid that cutting unit.

Edge effect of treatment.--As was done with the larval dispersal data, all pheromone traps were partitioned, and the data processed and analyzed with the three variables--edge, center of cutting unit, and the adjacent controls.

In the OR, CC, and SEL there were highly significant differences between the edge, center, and controls of the three cutting units (table A-23) in the number of adult males trapped. The nonsignificance of the UR, however, is no doubt a reflection of the similarity of the stand environmental conditions within the cutting unit to those in the adjacent CON, as already shown for main effect of treatment in the DMRT on page 33.

Notwithstanding the differences, as indicated above, none of the four stands had an edge effect on the flight of adult male moths. In the SEL, OR, and CC the number of moths trapped in the center and edge of the cutting units was not significantly different, but in all three stands significantly more moths were caught in the control than in either the edge or center of the unit (table A-24). This is a main treatment effect and not an edge effect. The insignificant differences in moth catches in the edge, center, and control, as shown in the DMRT (table A-24), further support the fact that the environmental changes in the forest created by the UR are really not enough to change the flight behavior of adult males from their dispersal patterns in the undisturbed forest.

In summary, even in these relatively small, 15-acre cutting units at Lubrecht, moths do not fly out into the center of the cutting units in any fewer numbers than they are attracted to the baited traps on the periphery of the unit; i.e., no edge effect.

Moth Dispersal at Lubrecht in 1979

In the second posttreatment season (1979), the distribution of moth catches (table A-25) in the five units at Lubrecht followed the same pattern as they did in 1978. Again, moth catches were very closely related to severity of treatment, but the similarity between the UR and the CON was not as close as it was in 1978. Part of this may have been because 15 more control plots were established in 1979. But as in 1978, the fewest number of moths were trapped in the clearcut, and an intermediate very similar catch in the SEL and OR.

As in 1978, the range in values between the minimum and maximum number of moths caught in each unit indicated a heterogeneous distribution. A chi-square analysis supports that heterogeneity, as follows:

<u>Stand treatment</u>	<u>Chi-square in 1979**</u>
Selection	595.6
Understory removal	419.9
Overstory removal	455.6
Clearcut	198.0
Control	385.1

**Highly significant.

Because of the heterogeneity of means, all 1979 data was transformed according to the square root transformation $\sqrt{x + 3/8}$.

Main effect of treatment.--Again in 1979, the second year after cutting, there was a highly significant difference between stand treatment in the number of moths caught (table 5).

Table 5.--Partial ANOVA of the number of WSBW adult males caught at five stands in 1979, Lubrecht Experimental Forest

<u>Source of variation</u>	<u>df</u>	<u>Mean square</u>	<u>F</u>	<u>PR>F</u>
Treatment	4	541.5	199.0**	0.0001
Error	184	2.7		

**Highly significant.

In general, the 1979 results support those found in 1978, and that is the close relationship of number of moths trapped to the "severity of treatment"; the more drastic the treatment, the fewer moths caught.

The DMRT of the ANOVA (table 5) shows the same rankings of treatments as in 1978 with the groupings somewhat different, as indicated below:

<u>Stand treatment</u>	<u>Number samples</u>	<u>Number moths per trap</u>	<u>Grouping¹</u>
Control	30	15.0	A
Understory removal	45	11.3	B
Selection	32	9.3	C
Overstory removal	39	8.8	C
Clearcut	43	4.4	D
df = 184		Mean square = 2.72105	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Most moths were caught in the CON and the UR, although the differences between the two are significant in 1979, where they were not in 1978. Also in 1979, the DMRT above shows no significant difference in the numbers of moths trapped in the SEL and OR units, although the mean number of moths trapped in the SEL is somewhat higher than those in the OR. Because of the difference in the "severity" of the silvicultural treatment between the SEL and OR, one would have expected significantly more moths trapped in the SEL, as in 1978.

The highly significant difference in the number of moths trapped between stands in 1979 is also indicated in an ANACOVA (table 6).

Table 6.--Partial ANOCOVA, with 1978 as covariate, of the number of WSBW adult males caught at five stands in 1979, Lubrecht Experimental Forest

<u>Source of variation</u>	<u>df</u>	<u>Mean square</u>	<u>F</u>	<u>PR>F</u>
Treatment	4	443.4	211.2**	0.0001
Error	167	2.1		

**Highly significant.

Moreover, the DMRT for moths in 1979, associated with the ANACOVA (1978 as a covariate) (in table 6) partitions out the differences between stands as follows:

<u>Stand treatment</u>	<u>Number samples</u>	<u>Number moths per trap</u>	<u>Grouping¹</u>
Control	15	15.7	A
Understory removal	45	11.3	B
Selection	32	9.3	C
Overstory removal	39	8.8	C
Clearcut	42	4.5	D
df = 167		Mean square = 2.13313	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Edge effect of treatment.--In 1979 there was a highly significant difference in the number of moths trapped in the center, edge, and adjacent controls of all units, including the UR (table A-26). (Recall that in 1978, there was an insignificant difference in these three variables in the UR [table A-23]).

The only edge significant effect, though weak, in 1979 is shown in the CC where populations in the undisturbed forest are significantly higher than those in the edge of the CC, which are significantly higher than those in the center of the unit (table A-27). Although there was an apparent edge effect in the CC in 1978, it was not significant (table A-24).

Moth populations in both the center and edge of the UR unit were significantly lower than moth catches in the adjacent CON (table A-27). This shows a treatment effect, not an edge effect, and a change in moth behavior in this unit in 1979, compared to 1978 when catches within the unit were the same as in the CON (table A-24).

Other than the variations in moth catches as discussed above for the CC and UR in 1979, moth behavior in the SEL and OR in 1979 (table A-27) was essentially the same as in 1978 (table A-24). In both cutting units and in both years, a treatment effect was shown but not an edge effect, in that significantly more moths were caught in the adjacent undisturbed forest than at either the edge or the center of the cutting unit. Moth catches between the edge and center were not significantly different.

NEWMAN RIDGE STUDY AREA

At Newman Ridge we measured moth dispersal in four clearcut units in 1978 and in two clearcut units in 1979, as follows:

<u>1978 Unit</u>	<u>1979 Unit</u>
East-1	South-1
North-1	East-3
South-1	
East-3	

Moth Dispersal at Newman in 1978

Clearcutting directly affected the dispersal behavior of adult male moths as indicated by the few moths caught out in the cutting units compared to the number trapped in the adjacent undisturbed stands (table A-28). Some significant features of the statistics related to moth catches as presented in table A-28 should be pointed out: 1) In all four units, the number of moths trapped in the clearcuts is well below the number caught in traps in the undisturbed forests adjacent to each cutting unit. 2) In all units, the standard deviations and the standard error of the mean are lower for data in the clearcuts than in the controls. 3) The range of minimum to maximum number of moths caught is generally lower in the cutting units compared to the controls. 4) In all four of the treatments, the minimum value for moth catches is zero. 5) The lowest means are in the two treatments with an east aspect.

The ranges in values, both in the treatments and the controls, again indicate a rather heterogeneous distribution of moth catches. The chi-square tests support this suspicion of heterogeneity, as follows:

<u>Unit</u>	<u>Chi-square values in 1978</u>	
	<u>treatment</u>	<u>control</u>
East-1	62.0*	62.5*
North-1	498.7*	36.5*
South-1	307.1*	43.9*
East-3	32.0*	102.2*

*Significant at 5-percent level.

Again, all data were transformed with the standard square-root transformation.

Main effect of treatment.--As one would suspect from table A-28, there was a significant difference in the number of adult male moths trapped between the eight areas (four treatments, four controls) at Newman Ridge in 1978 (table 7).

Table 7.--Partial ANOVA of the number of WSBW adult male moths caught at eight stands (four treatments and associated controls) in 1978, Newman Ridge study area

Source of variation	df	Mean square	F	PR>F
Treatment	7	71.8	47.6**	0.0001
Error	131	1.5		

**Highly significant.

The DMRT, associated with table 7, partitions the analysis as follows:

<u>Unit</u>	<u>Number samples</u>	<u>Number moths per trap</u>	<u>Grouping</u> ¹	
North-1 control	8	7.0		A
East-1 control	8	6.3		A
East-3 control	12	5.1		B
South-1 control	8	5.0		B
South-1	23	2.3		C
North-1	24	1.7	D	C
East-3	32	1.5	D	
East-1	24	1.0	D	
df = 131		Mean square = 1.50796		

¹Means with different Grouping letters are significantly different (Alpha level .05).

The most significant features of the above DMRT partitioning of the ANOVA are as follows:

1. Not unexpectedly, means in the four control areas are significantly higher than means in any of the treatments.
2. As far as the controls are concerned, means in control stands North-1 and East-1 are significantly higher than those in control stands East-3 and South-1.
3. Moth catches in South-1 are significantly higher than in the two east-facing clearcuts, East-1 and East-3, but not significantly higher than catches in north-facing stand North-1.
4. Moth catches in stands East-3 and East-1 are not significantly different from one another; nor are they significantly different from moth catches in stand North-1.

Edge effect of treatment.--At all four clearcut units in 1979, there was a highly significant difference in the number of moths caught in the center edge and adjacent controls (table A-29). The partitioning of these differences by clearcut unit is shown in the DMRT (table A-30).

The differences as shown in the DMRT in table A-30 are really not unexpected and can be explained based on the configuration of the units and the composition of the undisturbed adjacent stands in relation to the clearcuts themselves, as follows:

1. An edge effect is indicated for both units East-1 and South-1. Means in the adjacent controls are significantly higher than means at the edge of the units, which in turn are significantly higher than means in the center of the units. Both East-1 and South-1 are rectangular-shaped clearcuts with their long axes on the contour and abutted on their lower sides by a dense stand of undisturbed forest, and with their ends adjacent to only a lightly stocked forest. Hence, the center of both units is up the hill and away from the undisturbed forest, both by distance and by nature of the steep slopes.
2. Neither stand North-1 nor East-3 has an edge effect, even though in both units more moths were caught in traps at the edge of the stands (although insignificantly) than were in the center of the clearcuts.
 - a. East-3 is a relatively small unit and completely surrounded by a dense forest of large sawtimber-size trees. In this case, a significant edge effect could be masked by the surrounding stand as well as the size of the unit.

b. North-1 is surrounded on all sides by other clearcuts, with the exception of the south side near the west corner which is bounded for a short distance by an adjacent undisturbed forest. Hence, there is relatively little adjacent forest from which an edge effect can be produced. However, the higher (but insignificant) mean for edge compared to center, as shown for North-1 in table A-30, is due to a higher moth catch in those traps located along the south edge toward the west corner of the unit. This catch pattern indicates an edge effect, even though the DMRT analysis does not show it to be significant.

Moth Dispersal at Newman in 1979

Of the four clearcut units at Newman Ridge sampled in 1978, two were chosen in 1979 to be part of our nine intense site matrix. These two stands are South-1 and East-3.

As in 1978, the effect of clearcutting in the dispersal of adult males is indicated by the relatively few numbers of moths caught in the traps in the clearcuts compared to those caught in the adjacent undisturbed forests (table 8).

Table 8.--The mean number of adult male moths caught at two clearcut areas and their associated controls in 1978 at Newman Ridge study area, and associated statistics

Unit	Number traps	Number moths per trap	Std. dev.	Range min. max.	Std. error of mean
<u>South-1</u>					
Treatment	29	1.2	-	0 10	-
Control	12	52.0	-	15 188	-
<u>East-3</u>					
Treatment	31	7.9	7.3	0 27	1.31
Control	14	30.2	16.6	9 59	4.43

A comment or two should be made concerning the features of the statistics presented in table 8:

1. In both units, the moth catch in the clearcut treatment is well below the number caught in the adjacent control, especially in stand South-1.

2. Of the 29 traps set out in South-1 clearcut, moths were caught in only ten of them, with no catches in 19 traps. Because of these zeros, no standard deviations nor standard errors were computed, for either the treatment or the control.

3. The zero catches in 19 of 29 traps in clearcut South-1 support a very strong treatment effect in that unit, since an average of 52 moths were caught per trap in the adjacent undisturbed forest.

4. In unit East-3, the standard deviations and standard error of the mean are lower for the treatment data than the controls.

5. In both units, the range of minimum to maximum number of moths caught is less in the cutting units than in the controls, especially in stand South-1.

6. In both treatments, the minimum value for moth catches is zero.

7. In 1978, three times as many moths were caught in stand South-1 compared to stand East-3 (table A-28). In 1979, catches in stand East-3 are more than six times what they were in stand South-1.

The following chi-square analysis demonstrates the heterogeneity of the moth dispersal data in both the treatments and controls at Lubrecht in 1979:

<u>Stand</u>	<u>Chi-square values in 1979</u>	
	<u>treatment</u>	<u>control</u>
South-1	163.0**	480.5**
East-3	229.9**	119.0**

**All values highly significant.

Main effect of treatment.--Although the ANOVA and DMRT are not presented, both tests show that significantly more moths were caught in the adjacent controls than in either stand South-1 or stand East-3. In both cases, these 1979 analyses support the treatment effect shown in 1978 for these two clearcut units.

Edge effect of treatment.--There was a highly significant difference in the number of moths caught at the center, edge, and adjacent control in stand East-3 at Newman Ridge in 1979 (table 9).

Table 9.--Partial ANOVA of the number of WSBW adult male moths caught in the center, edge, and adjacent controls at stand East-3 in 1979, Newman Ridge study area

Source of variation	df	Mean square	F	PR>F
Edge	2	42.7	26.9**	0.0001
Error	42	1.6		

**Highly significant.

The significant effect of clearcut edge on dispersing moths is shown in the following DMRT.

NEWMAN RIDGE EAST-3 TESTING EDGE EFFECT FOR 1979

<u>Position</u>	<u>Number samples</u>	<u>Number moths per trap</u>	<u>Grouping</u> ¹
Control	14	5.3	A
Edge	13	3.3	B
Center	18	2.0	C
df = 42		Mean square = 1.59006	

¹Means with different Grouping letters are significantly different (Alpha level .05).

As shown, moth catches in the controls are significantly higher than those on the edge of the clearcut, which in turn are higher than moth catches in the center of the unit.

Although an analysis was not made for edge effect in stand South-1 in 1979, the data indicates an edge effect there too. More moths were caught in the controls than were caught in traps at the edge of the clearcut, which in turn caught more moths than traps in the center of the clearcut (table 10).

Table 10.--The mean number of adult male WSBW moths caught in the edge, center, and associated control at stand South-1 in 1979, Newman Ridge study area, with related data

Position	Number of traps	Number of traps catching moths	Total Number of moths caught	Number moths per trap
Control	5	5	173	34.6
Edge	7	6	25	4.2
Center	6	3	6	2.0

OTHER INTENSIVE STUDY SITES

In addition to studying the dispersal of WSBW moths at Lubrecht and Newman Ridge in 1979, we extended our studies to three other intensive sites shown with their number, name, silvicultural prescription, mean number of moths caught, and other statistics (table 11).

Table 11.--The mean number of adult WSBW male moths caught per trap at three intense study sites and their associated controls in 1979, and associated statistics

Stand	Silvicultural prescription	Number of traps	Mean Number of moths caught	Std. dev.	Range min.	max.	Std. error of mean
Valley	Selection	33	79.6	29.0	39	144	5.05
	Control	8	126.4	29.9	89	168	10.60
Chamberlain	Seed tree	55	35.6	22.5	2	115	3.04
	Control	14	311.4	62.4	223	439	16.68
Blue mountain	Clearcut	46	48.2	45.7	0	218	6.75
	Control	14	222.1	73.7	87	384	19.70

In all three stands, moth catches in the controls were higher than those in the treated areas, particularly at the Chamberlain seed tree and the Blue Mountain clearcut. Differences between moth catches in the treatment and control in the Valley Creek selection are indicated, but not as pronounced as in the other two stands.

The heterogeneity of moth catch distribution at these three study sites, particularly in the treatments, is shown in the chi-square analysis as follows:

<u>Stand</u>	<u>Chi-square values in 1979</u>	
	<u>treatment</u>	<u>control</u>
Valley creek	341.9*	49.9*
Chamberlain	6314.5*	92.4*
Blue mountain	1963.1*	318.2*

*All values significant at 5-percent level.

Again, all data were transformed according to $\sqrt{x + 3/8}$.

Main Effect of Treatment

An ANOVA (not presented) for all three intense study sites discussed in this section, and the respective controls for each of these three stands indicates a highly significant difference among means for the six situations tested--three treatments and three controls.

The partitioning of the differences is shown in the DMRT below:

<u>name</u>	<u>Stand</u>	<u>treatment</u>	<u>Number stands</u>	<u>Number moths per trap</u>	<u>Grouping¹</u>
Chamberlain		Seed tree (control)	14	17.5	A
Blue mountain		Clearcut (control)	14	14.7	B
Valley creek		Selection (control)	8	11.1	C
Valley creek		Selection	33	8.8	D
Blue mountain		Clearcut	46	6.3	E
Chamberlain		Seed tree	55	5.7	E
df = 207			Mean square = 4.01074		

¹Means with different Grouping letters are significantly different (Alpha level .05).

Several relationships between treatments and controls at these three intensive study sites are:

1. Moth catches in all three of the controls were significantly higher than catches in any three of the treatments, demonstrating a very strong treatment effect. Moreover, moth catches were significantly different between the three controls, most likely due to general population level differences between the three areas in 1979.

2. Catches were significantly higher in the Valley Creek selection than either the Blue Mountain clearcut or the Chamberlain seed tree. There were no significant differences between the latter two. One would expect catches to be higher at Valley Creek because the stand is much more dense than the other two. However, it is unexpected, hypothetically as well as based on other data presented above, that catches in the Blue Mountain clearcut would be higher (albeit not significantly) than in the Chamberlain seed tree unit.

3. In the Valley Creek selection unit where moth catches were highest, catches in its associated control were lowest, and in the Chamberlain seed tree unit where moth catches were lowest, catches in its associated control were highest.

4. In comparing the data in the DMRT above to the DMRT for stand East-3 at Newman Ridge, it is apparent that moth catches at Newman Ridge stand East-3 and its associated control were both lower than catches at all three intense sites and their respective controls. The low catches at Newman Ridge, compared to those for the three sites above, reflect the general population collapse at the Newman Ridge study area in 1979.

Edge Effect of Treatment

At all three stands, moth catches were significantly different between the center, edge, and the adjacent undisturbed forest (table A-31).

However, only at Blue Mountain is there an edge effect, where populations in the control were significantly higher than those in the edge of the treated area, which in turn are significantly higher than those in the center of the unit (table A-32). The analyses for Valley Creek and Chamberlain in table A-32 show a treatment effect. Catches in both units are higher in the controls than in the edge or center of the cutting unit, but there were no significant differences between the edge and center of the unit.

In some respects, the analyses as shown in the DMRT in table A-32 are not surprising. One would expect an edge effect at the Blue Mountain study area since it is a rather large clearcut. The stand at Valley Creek is well stocked, even after the cutting, so an edge effect would not be expected. The Chamberlain seed tree prescription would make one suspect that there would be an edge effect; one is indicated, but not significant in the DMRT.

Other Progress

In addition to the results presented above relative to spring dispersal of stage II larvae and the dispersal of adult male moths, progress was made and data gathered concerning:

1. Monitoring the spring dispersal of stage II dispersing larvae.
2. Measuring summer dispersal of stage I larvae.
3. The efficiency of Pherocon II traps and directional moth catches in other pheromone-baited traps.

Some of the data relative to this "other progress" is presented here. However, no analyses or interpretations have been made at this time, since progress in these areas was not part of our main objectives.

MONITORING LARVAL DISPERSAL

In addition to our regular measurements of dispersing larvae, we were able, with little extra effort or expense, to monitor over time the spring dispersal period at Lubrecht Experimental Forest in the spring of 1977, 1978, 1979 (and 1980), and the spring dispersal at Newman Ridge study area in 1979. This larval monitoring was done for two reasons:

1. To insure that the dispersal period was bracketed by the dates when we deployed and picked up the dispersal traps.
2. To provide data on spring dispersal that, when coupled with weather data, can be used to predict beginning and peak emergence in any given year.

Spring Dispersal Monitor at Lubrecht

In each year, of a given location at Lubrecht Experimental Forest we put out five dispersal traps once each week, beginning at or near the time we expected the first larvae to appear and continuing until we were reasonably sure the dispersal period was over. In some cases, we missed either the first or last dispersing larvae, but this was insignificant since few larvae were dispersing at the very beginning or very end of the dispersal period. The beginning, ending, and peak dispersal times for each of the 3 years is:

<u>Year</u>	<u>Spring dispersal stage II larvae</u>		
	<u>begin</u>	<u>peak</u>	<u>end</u>
1977	< 2 May	3 June	17 June
1978	<25 April	14 May	>11 June
1979	28 April	13-27 May	> 1 July

To give a better idea of the "spread" of larval dispersal over time, the weekly catches for 1979 are presented in table A-33. The data presented in table A-33 are of interest and are significant biologically. Although a couple of larvae were trapped at weeks two and six, the bulk of spring dispersing larvae did not begin to emerge until May 6. Two very definite peaks of emergence show between May 13 and 27. Emergence drops off rapidly after that, but larvae are still emerging as late as the first of July. Hence, in 1979 at least, the period over which stage II larvae were dispersing was more than eight weeks.

Also in 1979, to get a better idea of the period and peak of spring dispersal, we put out an additional two traps daily--beginning on 15 May and continuing until 17 June--at the same location as the weekly monitor traps. This daily trapping indicated that during the peak of larval emergence between 13 and 27 May, there were no real daily peaks of emergence (table A-34).

Spring Dispersal Monitor at Newman Ridge

At the Newman Ridge study area we also measured larvae at weekly (or near so) intervals during the spring of 1979. The first traps were installed on April 23, 1979. Trapping continued until July 2, 1979. The results of this monitoring effort are presented in table A-35. The low numbers of larvae on these monitor traps is also a reflection of the low WSBW populations in 1979 at the Newman Ridge study area as discussed earlier in the Results section. Although only six larvae were trapped, four of them were trapped during essentially the same period that the peak occurred at Lubrecht Forest (table A-33). Other than that, there is not much that can be said for the data in table A-35.

These data relative to the monitoring of spring dispersal have a variety of biological consequences. They help to explain the wide variation in larval development and could be used as a predictor for any treatments applied to late stage larvae.

At this time these monitor data are being applied and used by other researchers and pest management specialists in predicting the periods of spring larval dispersal in conjunction with the application of insecticides to protect cone crops.

SUMMER DISPERSAL OF STAGE I LARVAE

Since in 1979 nearly half of the traps set out to measure spring dispersing larvae were eaten by cattle, we redeployed traps at all sampling points to measure the summer dispersal of stage I larvae. The number of larvae trapped, with other pertinent data, are presented in table A-36.

Based on previous research, one can usually expect summer dispersing populations to be about ten times less than stage II spring dispersing larvae. The number of larvae per trap as shown in table A-36 are, however, more of a magnitude of 50 times fewer than spring-dispersing larvae. The low numbers in table A-36 may reflect an adverse environmental effect on WSBW larvae between the two dispersing periods.

Regardless of the low numbers, the treatment effect as reflected in table A-36 is what one might expect, with fewest larvae in the least dense stands, the clearcut, and overstory removal. There is little difference in the number of larvae trapped in the other three stands, though populations in the controls were more than six times what they were in the clearcut and nearly 13 times greater than in the overstory removal.

One must be careful comparing numbers of spring and summer dispersing larvae since spring populations originate from larvae overwintering on the bole and lower limbs of host trees, and summer larvae originate from the eggs laid on the crowns of the host trees.

SAMPLING ADULT DISPERSAL

In 1978 we collected considerable data concerning the efficiency of Pherocon II traps in attracting and holding adult male moths. We determined that these traps could hold only a certain number of moths and once that point was reached, the traps became less effective in attracting and holding additional males. These data were summarized in an earlier progress report.

Also in 1978, we determined that at the Lubrecht study site, there appeared to be a peak adult catch related, perhaps only weakly, to treatment. These data were also presented in an earlier progress report.

In 1979, we determined some relationships between the portion of the trap (using 2-quart traps as sampling units) catching moths and the direction in which the trap was placed. In general, traps were oriented in a north-south direction. We observed three relationships with this very preliminary directional catch research:

1. At all study sites, the directional catches were predominantly associated with the north end of the traps. At three of four study areas, north was generally downhill.
2. There appeared to be no treatment effect associated with directional catches. Regardless of severity of treatment, slope, aspect, or configuration of cutting unit, catches were pronounced to the north.
3. There appeared to be no edge effect associated with the directional catches. Even traps along timbered edges at the south sides of some units had moth concentrations at the north ends of the traps.

CONCLUSIONS

Based on the larval and adult dispersal data collected in 1978 and 1979 and analyzed and interpreted in the Results presented above, we are not prepared to make any management recommendations since, so far, data has been collected at only a portion of our intense study sites, which present only a fraction of our design matrix.

We are able, however, to make a statement or two on the apparent effects of treatment on dispersing larvae and adults.

Concerning Dispersal of Stage II Larvae

1. Some silvicultural prescriptions in small cutting units appear to affect the spring dispersal of stage II larvae. Other prescriptions, though varying widely in their "severity," appear to have no effect on dispersing larvae. At the Lubrecht site, the selection and overstory removal prescriptions appear to have some characteristics that often set one or both of these units apart from the rest, including the controls. Despite the wide differences in the "drasticity of treatment," clearcutting, overstory removal, or understory removal appear to have no differential effects on larval dispersal.

2. The size of the cutting unit, especially on level or only moderately relieved terrain, appears to be confounded with treatment effect. In smaller cuttings (ca. 15 acres), treatment effect, if present, may be masked by the edge effect of small units.

3. On steeper terrain and with somewhat intermediate size cutting units, 30-50 acres, there appears to be not only an effect of cutting treatment, but also a definite edge effect of undisturbed forests contiguous to the cutting units.

Concerning Dispersal of Adult Males

1. It appears that the number of adult males caught in pheromone-baited traps varies and is influenced by different stand conditions and/or silvicultural treatments, and that the influence of the treatment may be more pronounced as the flight period is at its peak.

2. In some cutting treatments and under some conditions, the number of adult males caught in traps appears to be influenced by the proximity of the traps in which they are caught to the undisturbed forest contiguous to the cutting treatment.

SIGNIFICANCE OF RESULTS

Data is presented in this report concerning several aspects of silvicultural prescriptions and their relationships with the behavior and dispersal of both larvae and adults. These data contribute to 1) the needs of practicing foresters, and 2) program objectives and the objectives of research at INT. As such, they can begin to be used in the development of WSBW management guidelines for the practicing forester.

Foresters in the Northern Rockies have been searching for some time for silvicultural guidelines concerning species composition, types of cuttings, etc., that can be employed or exploited to ameliorate or minimize the impact and/or incidence of damage. One of the objectives of the CANUSA-West Program is to develop environmentally acceptable silvicultural treatment techniques. Target #1 of the activity schedule is concerned with improving methods of assessing budworm population levels. One of the objectives of this study is to determine the influence of silvicultural practices on the dispersal of larvae and the flight and dispersal of WSBW adults. The objective of our INT research is to determine how we can manipulate our forests to ameliorate the impact of the WSBW. In part, the achievement of that objective is determining how stand manipulations affect the behavior and life processes of the WSBW which involve the dispersal and flight behavior of WSBW adults.

Direct users of these research results will be federal, state, and private forest managers seeking long-term solutions to some of their WSBW-related management problems. In addition, researchers needing information on populations to be used in measuring and predicting populations, as well as those needing both basic and applied biological information to augment their efforts, will be able to use the data generated in this study. For example: 1) co-investigator Dr. Clint Carlson, is and will be using larval and adult dispersal data in order to amalgamate the results of this study and his study, collected at the same study areas, into preliminary interpretations of the influence of silvicultural practices on regeneration development as related to western spruce budworm larval and adult behavior; 2) Cooperator Dr. Don Burnell, Washington State University, is dependent on this larval dispersal data for his modeling efforts involving western spruce budworm larval dispersal. He has already been supplied with all larval dispersal (and some adult) data we have collected to date, as part of CANUSA Program-West; and 3) Research entomologists at PSW and at FIDM R-1 are using spring larval dispersal data collected in this study in their work using chemical insecticides against early stage WSBW larvae, to protect cone and seed production.

In addition to collaborating scientists above, federal, state, and private resource managers who plan harvest cuttings can use the results of this research to evaluate silvicultural options available to them to reduce the susceptibility and vulnerability of forest stands to the WSBW. Data generated in this study will contribute to the needs of forest managers by:

1. Identifying those silvicultural practices that minimize the impact of the WSBW in the ecosystems of the Northern Rockies.
2. Providing the data base needed to develop modifications of silvicultural systems to allow forests to better coexist with the WSBW.
3. Advancing the state of knowledge of the complex interactions between the WSBW and site and stand conditions, environmental gradients, vegetation types, and other biotic and abiotic factors.

Other users of research data from this study will be researchers involved in preparing models of stand manipulations and insect interactions. Larval and adult dispersal are two of the key elements in the population ecology of the WSBW and consequently a significant element in the insect dynamics model. Any behavioral element of the WSBW influenced by, or related to, stand or site conditions is a key element in the integration of stand and insect models.

The major significance of these dispersal data will be realized as they are supplemented by similar data from other study sites in subsequent years under other stand conditions and silvicultural treatments, and collectively integrated with stand regeneration data being collected and analyzed as part of a closely related study under the direction of Dr. Clint Carlson. Data from the two studies will then be incorporated into the insect and stand dynamics model in the process of developing a pest management system for the WSBW.

RECOMMENDATIONS - WORK REMAINING ON STUDY

The overall plan and objective for this study call for measurements to be made on larval and adult dispersal related to a variety of stand and site variables at nine intense study sites in the Northern Rockies. During 1978, we made measurements of both larval and adult dispersal at two of these sites, Lubrecht Experimental Forest and the Newman Ridge study area. In 1979 we repeated the 1978 measurements and in addition measured adult dispersal at three other intense study sites.

In order to achieve the overall goals and objectives of this study, and in order to realize the complete benefits of this dispersal research and related studies of regeneration establishment as now directed by Clint Carlson working under a separately funded proposal, we must expand and continue this study to the nine intense study sites planned. Either of these two studies, without the other, will be incomplete in terms of providing land managers with the best entomological-silvicultural prescriptions.

Carlson and Fellin submitted in October 1980, a joint proposal for research in FY 1981 to continue the regeneration studies of Carlson and the closely related larval dispersal studies of Fellin, previously funded as two separate, but closely related studies. We can only recommend that this joint proposal receive Program support in FY 1981 so that these dovetailed studies of insect and stand relationships can continue, in order to achieve our overall objectives as outlined in the original proposals submitted in February 1978.

COOPERATION

This study is an integral part of the INT station spruce budworm research effort, and more specifically of the WSBW research team headquartered at the Missoula Forestry Sciences Lab. Listed on the title page are those at INT with whom the Principal Investigator is cooperating.

Specific cooperators and the nature of the cooperation is as follows:

Dr. Clinton C. Carlson, WSBW research team, Forestry Sciences Lab, INT Missoula. Joint selection of the study sites, sample plots and coordination of data collecting, data processing and analysis.

Larry Stipe and Donn Cahill, CANUSA entomologists, FIDM-R-1 and R-4, respectively; and Bill Wulf, CANUSA silviculturist, TM-R-1; in study area selection, population fix sampling, coordination with land managers and other cooperative efforts.

Dr. Gary Simmons, Dept. of Entomology and Forestry, Michigan State Univ., who is also involved in silvicultural guidelines for maximizing WSBW mortality through dispersal losses and natural enemies. Dr. Simmons has provided rough drafts of study plans and manuscripts which are valuable in planning and interpreting our work.

Dr. Harold Batzer, North Central Station, who has been a consultant in our dispersal work, who studied WSBW larval dispersal in the lake states in the late 1960's, and who is coauthoring a manuscript with Principal Investigator and others in the techniques of larval dispersal.

Dr. Dan Jennings, Northeast Station, who has been a consultant in our dispersal work, who studied larval WSBW larval dispersal in the lake states in the late 1960's, who is currently involved in larval dispersal studies in Maine, and who is also coauthoring manuscripts on techniques of larval dispersal.

Dr. Gary Daterman, Pacific Northwest Station, who is consultant in design of our studies and interpretation of results of adult dispersal and who is providing the pheromone used in our work.

Dr. Don Burnell, Washington State University, who is involved in studies of larval dispersal. Don has visited some of our study sites, discussed our work, objectives, and contributed to our interpretations. Our larval dispersal data will be available to him as it is processed during the late summer and fall of 1979.

Dr. Molly Stock, University of Idaho. For 2 years we have provided her with WSBW larval collections from several infestations in western Montana. She has also discussed and consulted with Principal Investigator concerning interpretations of Northern Rocky WSBW outbreaks.

Dr. Gary Long, Washington State University. We have provided Gary with maps of long-standing WSBW outbreaks in Northern Rockies and, as with others, consulted with him in interpretation and significance of WSBW outbreaks as related to his work.

Dr. Roy Beckwith and Russ Mitchell, Pacific Northwest Station. Principal Investigator provided week long tour in 1978 of Northern Rocky WSBW outbreaks. Discussed western Montana and northern Idaho situations, in relation to Pacific Northwest outbreaks.

Dr. Mark Houseweart, University of Maine, is a coauthor in manuscript on techniques of larval dispersal.

Dr. Rex Cates, University of New Mexico. We have acquainted Cates with Northern Rocky WSBW outbreak areas, source of "resistant" trees, and assisted in intervening with national forest personnel to find study areas and crew lodging area for Cates and crew.

Besides the above specific cooperators, the conduct of this study will require the cooperation of USFS Northern and Intermountain Regions, 1 and 4, respectively, for ADP screening of prospective study site conditions and use of the areas for conduct of the study. Other prospective coooperators for study site locations have been:

Forestry School, University of Montana, for use of Lubrecht E. F.
Bureau of Land Management, Department of Interior
Bureau of Indian Affairs, Department of Interior
States of Montana and Idaho Forestry Departments
Champion International
St. Regis Paper Company
Potlatch Paper Company

PROBLEMS ENCOUNTERED

We have encountered several problems, some major, some minor, during the life of this study.

Animals--the major problem we had in 1979 was the decimation of the majority of our traps at Lubrecht Experimental Forest by domestic livestock. We constructed a three-wire barbed-wire fence completely around the study area during the summer of 1979. This has resolved that type of problem at that study area. We have had some wild animal damage to both larval and adult dispersal traps. However, it is really insignificant and, moreover, unavoidable.

Snow--snow blocking roads to, and covering plots, in some of our study areas has been a problem. In some years and at some areas we have had to contract equipment to open roads to study areas. In other times and at other areas we have had to contract use of oversnow vehicles to transport men and equipment into the areas. Portions of some units had 2 to 3 feet of snow on them at the time larval dispersal traps were put out. As the study progresses to additional intense sites, access and snow removal will continue to be problems.

WSBW populations--at the Newman Ridge study area in 1979, a collapse of budworm populations between 1978 and 1979 resulted in no larvae being caught on the majority of traps. This precluded a statistical analyses of the data, although we were able to establish some trends and relationships. This population reduction could be a factor at other study sites as the study progresses.

Ash--though not occurring during the present reporting period, ash fell in the spring of 1980 while larval dispersal traps were deployed. This necessitated considerable extra work and an innovative process, to remove the ash and count the larvae.

TECHNOLOGY TRANSFER

Manuscripts

We are, at present, preparing and/or planning six manuscripts related to larval and adult dispersal, as follows:

1. A manuscript concerning larval dispersal as related to silvicultural practices based on data collected between 1973 and 1977, as part of larval dispersal studies conducted prior to the CANUSA Program.

2. A manuscript similar to #1 concerning larval dispersal data collected as part of the CANUSA Program. Data analysis and interpretations presented in this final progress report will form the basis of this paper.

3. A third manuscript will be prepared concerning adult dispersal data. Data analysis and interpretations presented in this final progress report will form the basis of this paper.

4. A manuscript concerning the procedures, problems, and techniques involved in measuring dispersal of spruce budworm larvae, coauthored by Dan Jennings, NE; Harold Batzer, NC; Dave Fellin, INT; and Mr. Houseweart, University of Maine. A large part of the data comes from research on WSBW larval dispersal done prior to the onset of the CANUSA Program--both East and West.

5. A manuscript presenting the spring dispersal period of stage II larval dispersal as related to degree day accumulation of heat, to be coauthored, Fellin and Theroux.

6. A manuscript describing the relation of extremely low winter temperatures related to survival of overwintering and subsequent dispersal of stage II larvae. This paper will be based on larval dispersal data gathered at Lubrecht Forest in 1977 (pre-CANUSA) and 1978-1979 data collected as part of our CANUSA-funded study.

Other

Besides papers planned or in preparation, data has been or is being disseminated by two other means:

1. In August 1979, Fellin presented a paper on WSBW dispersal at IUFRO conference, Sandpoint, Idaho.

2. We are planning a program at the spring meeting of the Northern Rockies Forest Pest Action Council to present the results of this and associated studies at INT in relation to silvicultural practices.

APPENDIX TABLES

Table 1.--The number of dispersing stage II WSBW larvae per $\frac{1}{4}$ m² reaching the forest floor at Lubrecht Experimental Forest in 1977, preharvest, with associated statistics

Stand treatment	Number of traps	Number of larvae	Std. dev.	Range		Std. Error of mean
				min.	max.	
Clearcut	43	47.5	16.3	16	90	2.5
Understory removal	44	56.6	30.6	18	143	4.6
Selection	31	41.2	16.6	14	75	3.0
Overstory removal	37	78.4	32.6	43	164	5.3
Control	15	42.2	20.8	12	82	5.4

Table 2.--The number of dispersing stage II WSBW larvae per $\frac{1}{4}$ m² reaching the forest floor at Lubrecht Experimental Forest in 1978, first year postharvest, with associated statistics

Stand treatment	Number of traps	Number of larvae	Percent change since 1977	Std. dev.	Range		Std. error of mean
					min.	max.	
Clearcut	39	34.1	-28	13.6	14	69	2.2
Understory removal	43	32.7	-42	14.3	10	88	2.2
Selection	32	43.0	+ 4	11.5	19	62	2.0
Overstory removal	39	32.0	-59	11.8	12	58	1.9
Control	15	25.2	-40	10.2	11	45	2.6

Table 3.--The number of dispersing stage II WSBW larvae per $\frac{1}{4}$ m² reaching the forest floor at Lubrecht Experimental Forest in 1979, second year postharvest, with associated statistics

Stand treatment	Number of traps	Number of larvae	Percent change since 1977	Percent change since 1978	Std. dev.	Range min. max.	Std. error of mean
Clearcut	10	58.2	+23	+70	21.7	21 79	6.9
Understory removal	24	54.5	- 4	+67	16.2	31 94	3.3
Selection	22	53.7	+30	+25	15.4	35 98	3.3
Overstory removal	13	30.0	-62	- 1	9.9	14 43	2.7
Control	28	39.0	- 8	+55	21.4	15 108	4.0

Table 4.--Portions of Duncan's Multiple Range Test and ANOVA showing changes in populations of dispersing stage II larvae between 1977 and 1978 at five stands, Lubrecht Experimental Forest

Stand treatment	Year				Mean square year error		F	PR>F
	$\bar{X}$	1977 N	$\bar{X}$	1978 N				
Selection	6.3	31	6.5	32	0.64	1.23	0.52	0.4731
Understory removal	7.3	44	5.6	43	61.20	2.57	23.76*	0.0001
Overstory removal	8.7	37	5.6	39	185.70	1.90	96.90*	0.0001
Clearcut	6.8	43	5.8	39	22.50	1.40	16.44*	0.0001
Control	6.3	15	5.0	15	14.10	1.80	7.69*	0.0098

*Means in 1977 are significantly higher than those in 1978.

Table 5.--Portion of ANOVA showing differences in populations of dispersing stage II larvae between 1977, 1978, and 1979 at five stands, Lubrecht Experimental Forest

Stand treatment	Mean square		F	PR>F
Selection	Year	6.3	5.43**	0.0061
	Error	1.2		
Understory removal	Year	37.5	16.46**	0.0001
	Error	2.3		
Overstory removal	Year	108.6	61.00**	0.0001
	Error	1.8		
Clearcut	Year	17.5	11.80**	0.0001
	Error	1.5		
Control	Year	8.5	4.02*	0.0236
	Error	2.1		

**Highly significant differences between years.

*Significant difference between years.

Table 6.--Portions of Duncan's Multiple Range Test showing changes in populations of dispersing stage II larvae per $\frac{1}{4}$ m² between 1977, 1978, and 1979 under five stand treatments, Lubrecht Experimental Forest

Year	Number samples	Number larvae	Grouping ¹
<u>SELECTION</u>			
79	22	7.3	A
78	32	6.5	B
77	31	6.3	B
df = 82		Mean square = 1.16955	
<u>UNDERSTORY REMOVAL</u>			
79	24	7.3	A
77	44	7.3	A
78	43	5.6	B
df = 108		Mean square = 2.27683	
<u>OVERSTORY REMOVAL</u>			
77	37	8.7	A
78	39	5.6	B
79	13	5.4	B
df = 86		Mean square = 1.78075	
<u>CLEARCUT</u>			
79	10	7.5	A
77	43	6.8	A
78	39	5.8	B
df = 89		Mean square = 1.48647	
<u>CONTROLS</u>			
77	15	6.3	A
79	28	6.1	A
78	15	5.0	B
df = 55		Mean square = 2.10555	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 7.--Portion of covariance analysis showing stand treatment effects on dispersing larvae in 1978 and 1979, using 1977 and 1978 as covariates, Lubrecht Experimental Forest

<u>ANALYSIS OF COVARIANCE</u>				
Source variation	df	Mean square	F	PR>F
<u>LUBRECHT 1978 WITH 1977=CV</u>				
Stand treatment	4	7.75	4.45	0.0019
Covariate	1	5.57	3.19	0.0758
Error	163	1.74		
<u>LUBRECHT 1979 WITH 1977=CV</u>				
Stand treatment	4	13.94	9.54	0.0001
Covariate	1	0.32	0.22	0.6410
Error	76	1.46		
<u>LUBRECHT 1979 WITH 1978=CV</u>				
Stand treatment	4	13.94	10.86	0.0001
Covariate	1	13.83	10.77	0.0016
Error	76	1.28		

Table 8.--Portions of Duncan's Multiple Range Test showing treatment effects on dispersing larvae per $\frac{1}{4}$ m² in 1978 and 1979, using 1977 and 1978 as covariates, Lubrecht Experimental Forest

Stand treatment	Number samples	Number larvae	Grouping ¹
<u>VARIABLE LARVAE-1978 - COVARIATE LARVAE-1977</u>			
Selection	31	6.6	A
Clearcut	42	5.7	B
Understory removal	44	5.7	B
Overstory removal	37	5.6	B
Control	15	5.0	B
df = 163		Mean square = 1.74363	
<u>VARIABLE LARVAE-1979 - COVARIATE LARVAE-1977</u>			
Clearcut	10	7.5	A
Understory removal	24	7.3	A
Selection	22	7.3	A
Control	13	5.7	B
Overstory removal	13	5.4	B
df = 76		Mean square = 1.46197	
<u>VARIABLE LARVAE-1979 - COVARIATE LARVAE-1978</u>			
Clearcut	10	7.5	A
Understory removal	24	7.3	A
Selection	22	7.3	A
Control	13	5.7	B
Overstory removal	13	5.4	B
df = 76		Mean square = 1.28419	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 9.--Portions of ANOVA showing effects of stand edge on dispersing stage II larvae in 1977 (pretreatment) in four areas where cuttings were to be made, Lubrecht Experimental Forest

Stand treatment	Source of variation	df	Mean square	F	PR>F
Selection	Edge	2	0.50	0.25	0.7787
	Error	43	1.99		
Understory removal	Edge	2	6.08	1.76	0.1819
	Error	56	3.46		
Overstory removal	Edge	2	30.45	10.84**	0.0001
	Error	49	2.81		
Clearcut	Edge	2	1.95	1.11	0.3365
	Error	55	1.76		

**Highly significant differences between numbers of larvae trapped on edge of unit compared to center.

Table 10.--Portions of Duncan's Multiple Range Test showing effects of stand edge on dispersing larvae per $\frac{1}{4}$ m² in 1977 in four areas where cuttings were to be made, Lubrecht Experimental Forest

Position	Number samples	Number larvae	Grouping ¹
<u>SELECTION</u>			
Center	10	6.6	A
Control	15	6.3	A
Edge	21	6.2	A
df = 43	Mean square = 1.98908		
<u>UNDERSTORY REMOVAL</u>			
Center	22	7.5	A
Edge	22	7.1	A
Control	15	6.3	A
df = 56	Mean square = 3.46218		
<u>OVERSTORY REMOVAL</u>			
Edge	20	8.7	A
Center	17	8.7	A
Control	15	6.3	B
df = 49	Mean square = 2.81031		
<u>CLEARCUT</u>			
Edge	21	7.0	A
Center	22	6.6	A
Control	15	6.3	A
df = 55	Mean square = 1.76171		

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 11.--Portions of ANOVA showing effects of stand edge on dispersing stage II larvae in 1978 (first-year post-treatment) in four treatments of stands cut in 1977, Lubrecht Experimental Forest

Stand treatment	Source of variation	df	Mean square	F	PR>F
Selection	Edge	2	14.02	16.78**	0.0001
	Error	44	0.84		
Understory removal	Edge	2	4.18	2.34	0.1057
	Error	57	1.79		
Overstory removal	Edge	2	6.71	7.40**	0.0015
	Error	51	0.91		
Clearcut	Edge	2	4.13	1.70	0.1921
	Error	54	2.42		

**F value highly significant.

Table 12.--Portions of Duncan's Multiple Range Test showing effects of stand edge on dispersing stage II larvae per $\frac{1}{4}$ m² in 1978 (first year posttreatment) in four treatments of stands cut in 1977, Lubrecht Experimental Forest

Position	Number samples	Number larvae	Grouping ¹	
<u>SELECTION</u>				
Center	10	7.0	A	
Edge	22	6.3	A	
Control	15	5.0	B	
df = 44		Mean square = 0.836139		
<u>UNDERSTORY REMOVAL</u>				
Center	23	5.9	A	
Edge	22	5.4	B	A
Control	15	5.0	B	
df = 57		Mean square = 1.78923		
<u>OVERSTORY REMOVAL</u>				
Edge	20	6.1	A	
Center	19	5.1	B	
Control	15	5.0	B	
df = 51		Mean square = 0.0907286		
<u>CLEARCUT</u>				
Edge	21	5.9	A	
Center	21	5.4	A	
Control	15	5.0	A	
df = 54		Mean square = 2.42554		

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 13.--Portion of ANOVA showing effects of stand edge on dispersing stage II larvae in 1979 (second year posttreatment) in two stands, Selection and Understory Removal, Lubrecht Experimental Forest

Stand treatment	Source of variation	df	Mean square	F	PR>F
Selection	Edge	2	9.2	5.12**	0.0098
	Error	47	1.8		
Understory removal	Edge	2	10.8	5.88**	0.0051
	Error	49	1.8		

**F value highly significant.

Table 14.--Portion of Duncan's Multiple Range Test showing effects of stand edge on dispersing stage II larvae per $\frac{1}{4}$ m² in 1979 under two stand treatments, Selection and Understory Removal, Lubrecht Experimental Forest.

Position	Number samples	Number larvae	Grouping ¹
<u>SELECTION</u>			
Center	8	7.5	A
Edge	14	7.1	A
Control	28	6.1	B
df = 47		Mean square = 1.79872	
<u>UNDERSTORY REMOVAL</u>			
Edge	12	7.6	A
Center	12	7.1	A
Control	28	6.1	B
df = 49		Mean square = 1.83275	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 15.--Portion of covariance analysis showing effects of stand edge on dispersing stage II larvae in 1978, using larval dispersal data from 1977 as covariate, under four stand treatments 1 year after harvest, Lubrecht Experimental Forest

Stand treatment	Source of variation	df	Mean square	F	PR>F
Selection	Edge	2	2.36	3.80**	0.03
	Covariate	1	0.01	0.01	0.93
	Error	42	0.62		
Understory removal	Edge	2	0.50	1.02	0.37
	Covariate	1	0.70	1.42	0.24
	Error	55	0.49		
Overstory removal	Edge	2	1.67	3.55**	0.04
	Covariate	1	0.21	0.44	0.51
	Error	48	0.47		
Clearcut	Edge	2	1.16	2.14	0.12
	Covariate	1	1.68	3.11	0.08
	Error	54	0.54		

**F value highly significant.

Table 16.--Portions of Duncan's Multiple Range Test showing edge effects on dispersing larvae per $\frac{1}{4}$ m² in 1978 using 1977 data as a covariate, Lubrecht Experimental Forest

Position	Number samples	Number larvae	Grouping ¹	
<u>SELECTION 1978 WITH 1977=CV</u>				
Control	15	2.4		A
Edge	21	1.9	B	A
Center	10	1.5	B	
df = 42		Mean square = 0.619438		
<u>UNDERSTORY REMOVAL 1978 WITH 1977=CV</u>				
Control	15	2.4		A
Edge	22	2.1		A
Center	22	2.1		A
df = 55		Mean square = 0.493706		
<u>OVERSTORY REMOVAL 1978 WITH 1977=CV</u>				
Control	15	2.4		A
Edge	20	2.2	B	A
Center	17	1.8	B	
df = 48		Mean square = 0.466751		
<u>CLEARCUT 1978 WITH 1977=CV</u>				
Control	15	2.4		A
Center	22	2.0		A
Edge	21	1.9		A
df = 54		Mean square = 0.536074		

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 17.--Portion of ANOCOVA showing effects of stand edge on dispersing stage II larvae in 1979, with 1978 as covariate, under two stand treatments, Selection and Understory Removal, Lubrecht Experimental Forest

Stand treatment	Source of variation	df	Mean square	F	PR>F
Selection	Edge	2	14.02	16.3**	0.0001
	Covariate	1	0.01	0.0	0.9469
	Error	43	0.86		
Understory removal	Edge	2	4.18	2.3	0.1099
	Covariate	1	0.02	0.01	0.9127
	Error	56	1.82		

**F value highly significant.

Table 18.--Portions of Duncan's Multiple Range Test showing edge effects on dispersing larvae per $\frac{1}{4}$ m² in 1979, with 1978 data as covariates, at two stands, Selection and Understory Removal, Lubrecht Experimental Forest

Position	Number samples	Number larvae	Grouping ¹
<u>SELECTION 1979 WITH 1978=CV</u>			
Center	10	7.0	A
Edge	22	6.3	A
Control	15	5.0	B
df = 43		Mean square = 0.855495	
<u>UNDERSTORY 1979 WITH 1978=CV</u>			
Center	23	5.9	A
Edge	22	5.4	A
Control	15	5.0	A
df = 56		Mean square = 1.82079	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 19.--The number of dispersing stage II WSBW larvae per $\frac{1}{4}$ m² reaching the forest floor at the Newman Ridge study area in 1978 and 1979, with associated statistics

Unit	Number of traps	Number of larvae	Std. dev.	Range		Std. error of mean
				max.	min.	
<u>1978</u>						
East-3	32	7.6	2.6	2	13	0.46
East-1	20	8.1	6.5	1	26	1.50
North-1	24	6.4	2.4	2	12	0.49
South-1	23	4.7	3.2	1	16	0.68
<u>1979</u>						
<u>East-1</u>						
Treatment	32	0.2	0.4	0	1	0.07
Control	7	0.9	0.9	0	2	0.34
<u>East-3</u>						
Treatment	53	0.1	0.3	0	1	0.04
Control	14	0.4	0.5	0	1	0.14
<u>North-1</u>						
Treatment	30	0.1	0.3	0	1	0.05
Control	8	0.1	0.4	0	1	0.13
<u>South-1</u>						
Treatment	57	0.2	0.4	0	2	0.05
Control	11	0.5	0.5	0	1	0.16
<u>South-1</u>						
Treatment	30	0.2	0.5	0	2	0.09
Control	8	0.1	0.4	0	1	0.13

Table 20.--Portion of ANOVA showing effects of stand edge on the number of dispersing WSBW larvae between center and edge of four clearcut units at Newman Ridge study area, 1978

Unit	Source of variation	df	Mean square	F	PR>F
East-1	Edge	1	0.24	1.05	0.3161
	Error	22	0.23		
North-1	Edge	1	2.24	2.19	0.1561
	Error	18	1.02		
South-1	Edge	1	4.94	23.47**	0.0001
	Error	21	0.21		
East-3	Edge	1	0.51	2.19	0.1493
	Error	30	0.23		

**Highly significant.

Table 21.--Portions of Duncan's Multiple Range Test showing differences in the numbers of dispersing WSBW larvae per $\frac{1}{4}$ m² between center and edge of four clearcut units at Newman Ridge study area, 1978

Position	Number samples	Number larvae	Grouping ¹
<u>EAST-1</u>			
Edge	8	2.7	A
Center	16	2.5	A
df = 22		Mean square = 0.227369	
<u>NORTH-1</u>			
Edge	6	3.2	A
Center	14	2.5	A
df = 18		Mean square = 1.02335	
<u>SOUTH-1</u>			
Edge	9	2.7	A
Center	14	1.8	B
df = 21		Mean square = 0.21049	
<u>EAST-3</u>			
Edge	19	2.9	A
Center	13	2.6	A
df = 30		Mean square = 0.231241	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 22.--The number of adult moths trapped in 1978 under four cutting treatments and an undisturbed adjacent forest in 1978 at Lubrecht Experimental Forest (with associated data)

Stand treatment	Number of traps	Number of moths per trap	Std. dev.	Range		Std. error of mean
				min.	max.	
Selection	32	63.7	29.3	26	170	5.2
Understory removal	45	152.8	53.7	55	287	8.0
Overstory removal	39	82.6	48.0	34	261	7.7
Clearcut	43	25.2	14.4	3	81	2.2
Undisturbed forest	15	157.8	60.4	78	241	15.6

Table 23.--Portions of ANOVA showing the effects of stand edge on the flight and dispersal of adult WSBW males in 1978 under four stand treatments where cuttings had been made in 1977, Lubrecht Experimental Forest

Stand treatment	Source of variation	df	Mean square	F	PR>F
Selection	Edge	2	105.8	27.8**	0.0001
	Error	44	3.8		
Understory removal	Edge	2	5.7	1.16	0.3203
	Error	57	4.9		
Overstory removal	Edge	2	67.8	12.13**	0.0001
	Error	51	5.6		
Clearcut	Edge	2	313.1	109.7**	0.0001
	Error	55	2.9		

**F values highly significant.

Table 24.--Portions of Duncan's Multiple Range Test showing effects of stand edge on the dispersal pattern of adult WSBW moths in 1978 under four stand treatments cut in 1977, Lubrecht Experimental Forest

Position	Number samples	Number moths per trap	Grouping ¹
<u>SELECTION</u>			
Control	15	12.4	A
Center	10	8.3	B
Edge	22	7.6	B
df = 44		Mean square = 3.80556	
<u>UNDERSTORY REMOVAL</u>			
Edge	21	12.7	A
Control	15	12.4	A
Center	24	11.7	A
df = 57		Mean square = 4.91123	
<u>OVERSTORY REMOVAL</u>			
Control	15	12.4	A
Edge	20	8.9	B
Center	19	8.8	B
df = 51		Mean square = 5.59278	
<u>CLEARCUT</u>			
Control	15	12.4	A
Edge	21	5.2	B
Center	22	4.6	B
df = 55		Mean square = 2.85453	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 25.--The number of adult moths trapped in 1979 under four cutting treatments and an associated undisturbed forest in 1979 at Lubrecht Experimental Forest (with associated data)

Stand treatment	Number of traps	Number of moths per trap	Std. dev.	Range		Std. error of mean
				min.	max.	
Selection	32	92.0	42.0	30	207	7.4
Understory removal	45	130.0	35.2	67	234	5.3
Overstory removal	39	80.7	30.9	37	153	4.9
Clearcut	43	20.7	9.7	6	43	1.5
Control	30	228.3	55.0	137	329	10.0

Table 26.--Portions of ANOVA showing the effects of stand edge on the flight and dispersal of adult WSBW males in 1979 under four stand treatments where cuttings had been made in 1977, Lubrecht Experimental Forest

Stand treatment	Source of variation	df	Mean square	F	PR>F
Selection	Edge	2	246.8	61.3**	0.0001
	Error	59	4.0		
Understory removal	Edge	2	125.2	45.9**	0.0001
	Error	72	2.7		
Overstory removal	Edge	2	322.9	102.6**	0.0001
	Error	66	3.1		
Clearcut	Edge	2	988.0	528.6**	0.0001
	Error	70	1.9		

**F values highly significant.

Table 27.--Portion of Duncan's Multiple Range Test showing effects of stand edge on the dispersal pattern of adult WSBW moths in 1979 under four stand treatments cut in 1977, Lubrecht Experimental Forest

Position	Number samples	Number moths per trap	Grouping ¹
<u>SELECTION</u>			
Control	30	15.0	A
Center	10	9.7	B
Edge	22	9.2	B
df = 59		Mean square = 4.02576	
<u>UNDERSTORY REMOVAL</u>			
Control	30	15.0	A
Edge	21	11.6	B
Center	24	11.0	B
df = 72		Mean square = 2.72673	
<u>OVERSTORY REMOVAL</u>			
Control	30	15.0	A
Edge	20	8.8	B
Center	19	8.8	B
df = 66		Mean square = 3.14692	
<u>CLEARCUT</u>			
Control	30	15.0	A
Edge	21	5.0	B
Center	22	4.0	C
df = 70		Mean square = 1.86915	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 28.--The number of adult moths caught in 1978 in four clear-cutting units and their associated controls at Newman Ridge study area (with associated data)

Unit	Number of traps	Number of moths per trap	Std. dev.	Range min. max.	Std. error of mean
<u>East-1</u>					
Treatment	24	1.1	1.6	0 7	0.33
Control	8	42.8	19.3	6 72	6.84
<u>North-1</u>					
Treatment	24	4.6	9.3	0 37	1.90
Control	8	50.6	16.1	31 78	5.70
<u>South-1</u>					
Treatment	23	7.6	9.9	0 32	2.06
Control	8	26.6	12.8	4 47	4.51
<u>East-3</u>					
Treatment	32	2.4	1.4	0 5	0.24
Control	12	28.8	16.1	4 52	4.65

Table 29.--Portion of ANOVA showing the effects of stand edge on the flight and dispersal of adult WSBW males in 1978 at four clearcut units, Newman Ridge study area

Unit	Source of variation	df	Mean square	F	PR>F
East-1	Edge	2	92.3	59.2**	0.0001
	Error	29	1.6		
North-1	Edge	2	84.5	89.6**	0.0001
	Error	29	0.9		
South-1	Edge	2	30.0	15.0**	0.0001
	Error	28	2.0		
East-3	Edge	2	55.8	64.0**	0.0001
	Error	41	0.9		

**F values highly significant.

Table 30.--Portions of Duncan's Multiple Range Test showing effects of stand edge on the dispersal pattern of adult WSBW moths in 1978 at four clearcut units, Newman Ridge study area

Position	Number samples	Number moths per trap	Grouping ¹
<u>EAST-1</u>			
Control	8	7.1	A
Edge	10	2.6	B
Center	14	1.1	C
df = 29		Mean square = 1.55826	
<u>NORTH-1</u>			
Control	8	6.4	A
Edge	8	1.5	B
Center	16	0.9	B
df = 29		Mean square = 0.942858	
<u>SOUTH-1</u>			
Control	8	5.0	A
Edge	9	3.4	B
Center	14	1.6	C
df = 28		Mean square = 2.01177	
<u>EAST-3</u>			
Control	12	5.2	A
Edge	19	1.7	B
Center	13	1.4	B
df = 41		Mean square = 0.8702	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 31.--Portion of ANOVA showing the effect of stand edge on the flight and dispersal of adult WSBW males at three intensive study sites in 1979

Study site	Source of variation	df	Mean square	F	PR>F
Valley Creek	Edge	2	18.7	7.6**	0.0017
	Error	38	2.5		
Chamberlain	Edge	2	785.7	252.2**	0.0001
	Error	66	3.1		
Blue Mountain	Edge	2	388.4	53.6**	0.0001
	Error	57	7.3		

**F values highly significant.

Table 32.--Portions of Duncan's Multiple Range Test showing effects of stand edge on dispersal patterns of adult WSBW moths at three intensive study sites in 1979

Position	Number samples	Number moths per trap	Grouping ¹
<u>VALLEY CREEK</u>			
Control	8	11.2	A
Edge	14	9.0	B
Center	19	8.7	B
df = 38		Mean square = 2.46907	
<u>CHAMBERLAIN</u>			
Control	14	17.6	A
Edge	30	6.1	B
Center	25	5.3	B
df = 66		Mean square = 3.11581	
<u>BLUE MOUNTAIN</u>			
Control	14	14.7	A
Edge	20	7.3	B
Center	26	5.7	C
df = 57		Mean square = 7.25149	

¹Means with different Grouping letters are significantly different (Alpha level .05).

Table 33.--Number of stage II WSBW larvae per $\frac{1}{4}$ m² trapped per week over a 14-week period at Lubrecht Experimental Forest, spring, 1979

Week	Date	Trap number					Total larvae
		1	2	3	4	5	
1	3/27 - 4/02/79	0	0	0	0	0	0
2	4/02 - 4/09/79	0	0	1	0	0	1
3	4/09 - 4/16/79	0	0	0	0	0	0
4	4/16 - 4/22/79	0	0	0	0	0	0
5	4/22 - 4/28/79	0	0	0	0	0	0
6	4/28 - 5/06/79	0	1	0	0	0	1
7	5/06 - 5/13/79	5	4	4	3	4	20
8	5/13 - 5/20/79	51	56	48	28	49	232
9	5/20 - 5/27/79	51	36	59	46	46	238
10	5/27 - 6/02/79	9	10	11	17	8	55
11	6/02 - 6/10/79	6	10	8	4	2	30
12	6/10 - 6/17/79	4	1	6	2	6	19
13	6/17 - 6/24/79	0	1	1	0	1	3
14	6/24 - 7/01/79	3	4	3	0	2	12

Table 34.--Number of stage II WSBW larvae per $\frac{1}{4}$ m² trapped per day over a 33-day period at Lubrecht Experimental Forest, spring, 1979

Date	Trap Number		Total larvae	Date	Trap number		Total larvae
	1	2			1	2	
5/15	7	10	17	6/01	2	2	4
5/16	1	4	5	6/02	0	0	0
5/17	6	12	18	6/03	4	2	6
5/18	10	11	21	6/04	0	0	0
5/19	6	8	14	6/05	2	0	2
5/20	3	6	9	6/06	0	0	0
5/21	13	9	22	6/07	0	1	1
5/22	3	5	8	6/08	0	0	0
5/23	8	3	11	6/09	0	0	0
5/24	2	1	3	6/10	1	0	1
5/25	1	0	1	6/11	0	0	0
5/26	1	0	1	6/12	2	0	2
5/27	1	1	2	6/13	0	0	0
5/28	0	0	0	6/14	0	0	0
5/29	0	0	0	6/15	2	4	6
5/30	1	0	1	6/16	1	0	1
5/31	0	1	1	6/17	0	0	0

Table 35.--Number of stage II WSBW larvae per $\frac{1}{4}$ m² trapped per week (approximately), over a 70-day period at Newman Ridge study area, spring, 1979

Date	Trap number					Total larvae
	1	2	3	4	5	
4/23 - 4/30/79	0	0	0	0	0	0
5/01 - 5/09/79	0	0	0	0	0	0
5/10 - 5/17/79	1	0	1	0	0	2
5/18 - 5/24/79	0	1	0	0	1	2
5/25 - 6/04/79	0	0	0	0	0	0
6/05 - 6/14/79	0	0	0	0	1	1
6/15 - 6/25/79	0	0	0	0	0	0
6/26 - 7/02/79	0	0	0	0	1	1

Table 36.--Dispersal of stage I WSBW larvae per $\frac{1}{4}$ m² at Lubrecht
Experimental Forest, summer, 1979

Stand treatment	Number of traps	Number of larvae per trap	Range	Std. error of mean
Selection	32	1.12	0-8	.08
Understory removal	45	1.06	0-6	.03
Controls	29	1.03	0-5	.06
Clearcut	41	0.15	0-3	.07
Overstory removal	35	0.08	0-1	.002

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